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RADIOGRAPHY AND RADIO-THERAPEUTICS

PART I.—RADIOGRAPHY

PLATE I.—THORAX, SHOWING EARLY TUBERCULOSIS OF LUNGS.

Taken with the plate upon the posterior aspect of the thorax, with intensifying screen. Single-impulse exposure, approximately $\frac{1}{100}$ second. Showing slight irregularity of right side of diaphragm, increased opacity of hilus shadows, with peribronchial thickening at the root of each lung. This can be seen passing upwards to the apices where the detail can be traced to the periphery of the lung.

RADIOGRAPHY

AND

RADIO-THERAPEUTICS

BY

ROBERT KNOX

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CAPTAIN R.A.M.C. (T.) 4TH LONDON GENERAL HOSPITAL (IN CHARGE OF X-RAY DEPARTMENT)

PART I

RADIOGRAPHY

WITH SEVENTY-EIGHT PLATES (ONE IN COLOUR) AND
THREE HUNDRED AND THIRTY-SEVEN ILLUSTRATIONS IN THE TEXT

NEW YORK: THE MACMILLAN COMPANY
LONDON: A. & C. BLACK, LTD.
1917

First Edition published in 1915 *in one volume*
Second Edition, revised and enlarged, published in 1917 *in two volumes—*
Part I. Radiography. Part II. Radio-Therapeutics

TO

ALEXANDER MORISON

M.D. (Edin.), F.R.C.P. (Lond. and Edin.)

IN RECOGNITION OF THE VALUABLE HELP AND KINDLY ENCOURAGEMENT FREELY RENDERED THROUGH MANY YEARS OF CLOSE ASSOCIATION

PREFACE TO SECOND EDITION

The first edition of this book was completed soon after the outbreak of war. The reception accorded to the writer's first attempt at authorship has been a matter of considerable gratification. The valuable suggestions of kindly critics have led to the addition of much new matter in the present volumes, and have encouraged him to venture further afield in the most interesting of the new additions to the science of medicine. The sections dealing with the military side of radiography and radio-therapeutics have been considerably enlarged.

The revision of the text under war conditions has not been easy owing to the urgent calls of work in connection with military duties, and the author claims the indulgence of his readers for any shortcomings in the present edition due to this cause. On the other hand, the unique opportunities offered by the vast amount of work dealt with have enabled him to add much new matter which may be helpful to other workers at the present time. The illustrations have been critically gone through and revised, and this has resulted in the addition of 24 plates and 150 illustrations in the text.

Wherever possible acknowledgment has been made in the text of the sources from which new matter has been obtained, but I should like here to record my indebtedness to the work of A. E. Barclay on the Oesophagus and Stomach. In the instrumental part many valuable hints have been obtained from *The Care and Management of Electrical Machinery*, published by the Vulcan Boiler and General Insurance Company Limited.

I take this opportunity of cordially thanking my colleagues at the 4th London General Hospital for the valuable help rendered in efforts to deal with the localisation and removal of foreign bodies, the diagnosis and treatment of war injuries, and, on the medical side, the treatment of those diseases which are amenable to radiation treatment. It is only by cordial collaboration between the radiologist and the surgical and medical experts that the best results can be obtained by the use of radiations. A fuller recognition of the value of the new agents will lead to closer collaboration in the future, and result in a rational estimate of the true value of these agents in practical work.

It is impossible to thank individually all those who have so willingly helped towards the production of the work, but my thanks are especially due to the following: the General Editor, Major John D. Comrie, R.A.M.C. (T.), who has again made valuable suggestions which have been incorporated in the text; my wife, Alice Vance Knox, M.B., for the great help she has rendered in the compilation of both editions, and for her valuable literary help in the text; Mr. C. E. Holland, M.A., for his valuable work in the photographic technique and for help in experimental work; Mr. H. A. Low for again rendering help in reading the proofs and for valuable practical suggestions in the arrangement of the book; and the manufacturers of apparatus for the sympathetic manner in which they have assisted in illustrating the work.

Mr. G. F. Westlake has greatly helped in experimental work, and this acknowledgment of indebtedness would be incomplete if it did not include the several workers in the X-ray departments at the hospitals of which I have charge. To Sister Bishop—in charge at King's College Hospital—I would specially extend my thanks for valuable help in the production of many interesting negatives, and to Mr. A. O. Forder for the preparation of a number of drawings and photographic prints.

To the publishers I would express my cordial thanks for the ready response they have made to the demand for enlargement, for the excellent manner in which they have supervised the production of the illustrations, and for the general format of the book.

R. KNOX.

38 Harley Street, W. 1,
August 1917.

PREFACE TO FIRST EDITION

The object of this work is to present to the student and practitioner in as concise and practical a form as possible the essential points in radiography, X-ray therapeutics, and radium therapy. The chief aim throughout has been to present these leading features in such a form that the beginner may easily acquire a working knowledge of radiography, radiation technique, and therapy. The book is therefore a practical one, theoretical considerations having been omitted as far as possible.

The section on radiography has been illustrated as fully as possible, care having been taken to select only illustrations which have a definite educational value. Much attention has been paid to important points in the practical working of apparatus, and it is hoped that the student will be carried from the technical details to a consideration of results obtained, and their bearing on the diagnosis of diseases. For this purpose a number of anatomical and pathological diagrams have been incorporated in the text, and I would like gratefully to acknowledge the valuable data gathered from well-known works on anatomy, pathology, medicine, and surgery. The following books have been freely used in the compilation of the text: Gray's *Anatomy*, Heath's *Anatomy*, Cunningham's *Anatomy*, Holden's *Osteology*, Rose and Carless's *Surgery*, Erichsen's *Surgery*, Allbutt's *System of Medicine*, Osler's *Practice of Medicine*, and many others.

I also wish to acknowledge the valuable help obtained from a number of electrical firms, and personally to thank Mr. Howard Head for reading and correcting the section on instrumentation, and for compiling a glossary of terms used in medical electricity. My thanks are also due to Mr. Schall for permission to print passages from his admirable descriptions of methods of measurement of X-rays, to Mr. Geoffrey Pearce for preparing several drawings of apparatus, and to Mr. Andrews for many valuable suggestions regarding the X-ray tube and its manipulation.

I am also indebted to Mr. Thurstan Holland for several valuable prints, and for many hints on radiographic technique. Dr. R. W. A. Salmond has contributed several interesting prints, and has rendered some assistance in the preparation of parts of the text. My thanks are also due to Mr. E. H. Shaw, pathologist to the Great Northern Central Hospital, for help in the descriptions of sections from tumours treated by radiations. Mr. A. H. Booker has been responsible for the preparation of the greater part of the prints from which the illustrations have been taken and also for the excellent micro-photographic work.

For the section on Radium Therapy Mr. C. E. S. Phillips, F.R.S.E., has been good enough to write a special article on the Physics of Radium.

I must also thank most heartily the General Editor, Dr. John D. Comrie, for in the first instance suggesting the book and then for indicating the combination of the allied subjects to be included in it ; also for many valuable suggestions during the preparation and progress of the book. The idea of producing the plate illustrations in negative and positive is entirely his, and adds greatly to their value.

I am also greatly indebted to my old friend Alexander Mackay, B.A., for valuable help in arranging the text and correcting the proofs.

The index has been prepared by Mr. H. A. Low, and I gratefully acknowledge the invaluable assistance that he has given me at all times ; I wish also to express my appreciation of his unfailing courtesy during many hours of close association.

Thanks are also due to my colleagues at the Cancer Hospital, King's College Hospital, and the Great Northern Central Hospital, for their help, always most readily given, on the many difficult points in diagnosis which are constantly encountered, and for the great help they have given in following up cases in which a radiographic diagnosis has been confirmed or otherwise in the operating room. The value of such confirmation or negation is very great, as it enables the radiographer to verify his observations on debatable and doubtful points, and renders the help he is able to give the physician or surgeon of much greater value. The importance of this co-operation is referred to in the text, and I consider it indispensable if the full value of the methods described in this book is to be obtained.

It is impossible to thank adequately all those who have assisted me in the production of the numerous plates which make up the list of illustrations, but I would like to tender my cordial thanks to the members of the Assistant and Nursing Staffs of the Great Northern Central Hospital, the Cancer Hospital, and King's College Hospital, all of whom have contributed to the whole, and without whose loyal and keen interest and help this work could not have been produced.

ROBERT KNOX.

CONTENTS

PART I.—RADIOGRAPHY

LIST OF ILLUSTRATIONS

FULL-PAGE PLATES

Most of the radiographic illustrations in the plates have been reproduced in negative and positive form, the object being to present the reader with what is actually seen when a negative and positive are examined. When comparing the two side by side it will be seen that the one is complementary to the other. For convenience of comparison the negative and positive have been reproduced from the same aspect ; in actual practice the one is the reverse of the other.

The plates marked with an asterisk are examples of the type of radiogram that may be obtained if the data given in the Table on p. xvi are carefully studied and applied.

In order to assist the radiologist in the estimation of exposures, the following table has been compiled from experience acquired in the use of an apparatus used at King's College Hospital. The outfit consists of a large coil used for single-impulse work,—approximately a 20-inch spark-gap—which is used in conjunction with a single-point electrolytic interrupter and a tungsten target tube. The table gives all particulars necessary for the production of radiographs of any part of the body. A large number of the illustrations shown in the book were obtained under these conditions. The figures so produced are marked with an asterisk in the list of illustrations. It may not be possible to reproduce these results under different conditions, but the underlying principle does not vary, and as the table is the result of practical work, it should be a useful guide.

Part.	Distance from A.C. (inches).	Spark gap (inches).	Primary. (Amp.)	Secondary. (Milliamp.)	Time. (Sec.)	Milliamp.-seconds.
Skull (ant.-post.) . . .	20	6	11	4	40	160
,, (lateral)	20	5½	11	4½	20	90
Sinuses (frontal) . . .	18	5½	11	4½	40	180
,, (sphenoidal, etc.) .	18	5½	11	4½	30	135
Spine, ant.-post. (cervical) .	20	4½	12	4½	15	67½
,, ,, (dorsal) .	24	5	11	4	45	180
,, ,, (lumbar) .	24	4½	12	5	50	250
Scapula	20	4½	12	4½	25	112½
Shoulder-joint	18	4	13	5	15	75
Humerus	18	4	13	5	10	50
Elbow-joint (ant.-post.). .	16	4	13	5	6	30
,, (lateral) . .	16	4	13	5	7	35
Forearm (ant.-post.) . .	16	4	13	5	6	30
,, (lateral) . . .	16	4	13	5	8	40
Wrist (ant.-post.) . . .	16	4	13	5	4	20
,, (lateral)	16	4	13	5	6	30
Hand (ant.-post.) . . .	16	4	13	5	2	10
,, (lateral)	16	4	13	5	4	20
Pelvis	19	5	12	4	45	180
Hip-joint	19	5	12	4	40	160
Femur (ant.-post.) . . .	19	4½	13	4½	25	112½
,, (lateral) . . .	19	4½	13	4½	20	90
Knee (ant.-post.) . . .	18	5	13	4½	12	54
,, (lateral)	15	4	13	5	8	40
Leg (ant.-post.) . . .	18	4	13	5	8	40
,, (lateral)	18	4	13	5	7	35
Ankle-joint (ant.-post.) . .	18	4	13	5	7	35
,, (lateral) . .	18	4	13	5	6	30
Foot (ant.-post.) . . .	18	4	13	5	8	40
,, (toes only, ant.-post.) .	18	4	13	5	4	20
,, (lateral)	18	4	13	5	6	30

For the examination of the alimentary system with the opaque meal the intensifying screen is used, the exposure varying from the single-impulse to the time exposure of one second. Most of the thoracic work is done with the single-impulse exposure.

ILLUSTRATIONS IN THE TEXT

INTRODUCTORY

The path of the beginner in X-ray work is beset with difficulties which are accentuated when, as too often happens, he is not conversant with the technical details of the apparatus with which he obtains the results. This technical side of radiology is now very complicated and promises to become more so in the future. What, then, are the essentials of the equipment of the future radiologist ? A knowledge of physics will greatly aid in the understanding of the principles underlying the action of radiations upon photographic plates and tissues.

The worker who hopes to study the subject seriously must therefore be trained in physics. He must also have a knowledge of the construction of electrical apparatus. Possibly in the future special courses of instruction in these subjects at the medical schools and at schools specially devoted to physics, radio-therapeutics, and radiography, will meet the needs of the student and in course of time supply the demand for highly-trained experts in radiology.

In introducing to the beginner a subject of so complex a nature as X-rays there are several vital though elementary factors that can best be dealt with in an introductory chapter, which it is hoped will enable the reader to approach the more detailed descriptions in later parts of the book with a degree of foreknowledge which should enable him to understand clearly the principles that have led to their production.

The Discovery of X-Rays.—The discovery of X-rays was made by Röntgen in April 1895, and the first announcement of his discovery was given in a paper read at the Wurzburg Physico-Medical Society on December 28, 1895. Röntgen had been led to it by the work of Lenard, and Lenard, in common with many other scientists, was following the lead of Sir William Crookes. The discovery therefore goes back to the invention of Crookes's vacuum tubes. It was advanced by the work of Stokes and others on fluorescence.

The actual discovery was accidental, like other epoch-marking discoveries in science.

During the course of a search for invisible light rays, Röntgen turned on a low-pressure discharge tube, which was completely enclosed in black paper, when a fluorescent screen which was lying in the vicinity of the tube showed marked fluorescence while the tube was in action ; obviously some unknown radiation was at work and Röntgen quickly realised that he was dealing with a new agent. Further experiments led to the discovery of the new radiation, which he promptly designated as X-rays, and the name has remained from that time.

In this simple way one of the most important discoveries in physics was made ; one which in itself, and together with other discoveries, such as radio-activity by M. and Mme. Curie, has gone far to revolutionise our conceptions of matter, and which has in the short period of twenty years developed new and invaluable aids in practical medicine, diagnostic and therapeutic, agents which are yet in their infancy and which when developed further may be of incalculable value to humanity.

Lenard missed priority over Röntgen, but only just missed it ; he had observed, when working with a Crookes's tube, that if a thin plate of aluminium were let into a little window cut in the tube, rays of some kind were still able, more or less, to pass through the aluminium, but what they could do after that he did not discover. Then followed Röntgen's discovery in 1895.

Those whose memories go back to 1895 will remember the amount of interest taken in the new discovery throughout the whole world—the discovery being heralded in all countries and quickly taken up by many workers ; few of us could at that time realise the immense importance of the discovery, none of us could possibly have foreseen the enormous strides which have placed the benefits of Röntgen's discovery within the reach of all, or have foretold that the simple apparatus in use in 1895 would in 1917 be replaced by the highly technical electrical apparatus now used to excite the X-ray bulb. For a number of years the exciting apparatus was far in excess of the capacity of the best X-ray tubes. Now in 1917 we have a tube which is capable of taking the most powerful electrical discharges with safety. So in the brief period of twenty years we have the initial discovery followed by the production of highly specialised apparatus, and the application of the rays by medical men to the diagnosis and treatment of disease.

In order to understand the principles of construction of an X-ray tube, and its action, it will be necessary to briefly describe (1) the production of X-rays ; (2) the apparatus necessary to excite the X-ray bulb, the nature of the cathode stream, and the part it plays in the production of X-rays. These points are dealt with in the succeeding text, but in order to put them clearly before the beginner they are briefly described here.

An X-ray bulb consists essentially of the following parts :

(1) Anode. (2) Cathode. (3) Anti-cathode.

A simple form of X-ray bulb is illustrated at p. 55 (Fig. 39). When a current of electricity—the source from which this is derived is immaterial, so long as the tension is high—is passed through an X-ray bulb (or for simplicity of illustration through a glass tube which has been exhausted of atmospheric air), it passes from the positive to the negative pole if it has been connected up properly. Various methods may be employed to change a low- into a high-tension current.

The anode is the electrode through which the current enters the tube; the cathode is the electrode by which the current leaves the tube.

A stream of electrons is produced at the cathode, known as cathode rays; these are capable of being deflected by a magnetic field.

A pencil of cathode rays is focused on the target or anti-cathode; from the point of impact of the cathode rays on the anti-cathode, X-rays are given out in all directions.

X-rays are invisible, the pale green fluorescence on the bulb is due to reflected cathode rays from the anti-cathode striking the glass wall of the bulb. The Coolidge tube shows hardly any of this fluorescence.

Excitation of the X-Ray Bulb and the production of X-rays from it. —An induction coil is the form of apparatus most generally used. This is merely a device for transforming a low potential current into a high potential current; the source of the low potential current may be one of a number; the various methods of obtaining it are described in detail later. For the purpose of demonstration we will assume that the low potential current is obtained from a battery of a few cells.

An induction coil consists essentially of a cylindrical iron core round which is wound a coil of insulated wire. Around this primary coil the secondary is arranged in a number of coils of finer wire, consisting of many thousands of turns; these coils are also carefully insulated. An interrupter is required to make and break the current in rapid succession.

A condenser is provided when a mercury interrupter is employed; this offers an alternative path to the current at break.

The terminals of the coil are connected to the terminals of an X-ray tube, the positive to the anode and the negative to the cathode.

The current from the source of supply, either a battery or derived from the electrical mains, flows continuously from positive to negative; it is supplied to the terminals of the coil and at the same time to the interrupter which is in the circuit; the result of the rapidly-repeated interruptions is that at each "make" a momentary induced current appears in the secondary of the coil, and at every "break" a momentary current is induced in the opposite direction. In order to get the maximum effect from the X-ray bulb it is essential that the current should be as nearly as possible unidirectional; it is here that the condenser finds its chief use. The condenser stores the first rush of current at "make," while at "break" it discharges its current through the primary and demagnetises the core.

The induced currents in the secondary are therefore much fuller at make than at break; when the current appears at make it is known as "reverse" or "inverse" current. Coil construction is so arranged that a minimum of reverse current appears. The current which passes between the terminals of the coil and through the tube when it is in the circuit should pass in one direction and is chiefly derived from the "break." The great disadvantage of the induction coil as the means of transforming the low-tension current into one of high-tension lies in the difficulty of maintaining a unidirectional current; this difficulty is practically got rid of by employing the high-tension transformer, for by its aid we get rid of the need for an interrupter, and as reverse current is practically non-existent the need for valve tubes is also obviated.

There are many difficulties to be encountered in the working of apparatus. The chief of these lie in the manipulation of the X-ray bulb, for the vacuum of the tube is easily disturbed even in tubes which are exhausted to a high

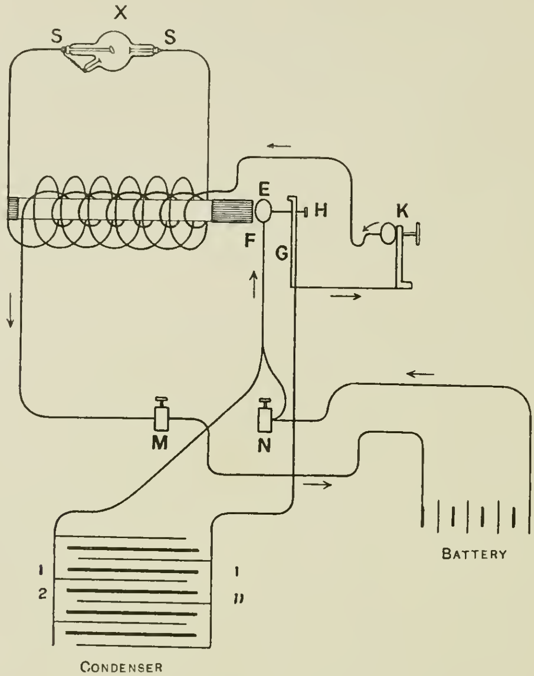


FIG. 1.—Diagram of arrangement of apparatus dealing particularly with the "path" of the current from source to X-ray bulb.

S, Secondary terminals, with X-ray tube in circuit.
M, N, Terminal screws for leads.
E, Metal disc or hammer.
K, Commutator.
X, X-ray tube.

The current enters at the screw N, ascends the spring F, passes through the screw to G, then to the commutator K, and through the primary back to the screw M, and from there to the battery. The passage of the current through the primary leads to two changes, (1) a momentary inverse current is induced in the secondary coil ; this is known as the current at "make" ; (2) the core is magnetised and attracts the metal disc E on the spring F ; as a result the current is interrupted in its flow to the primary.

When the current in the primary is checked, the core becomes demagnetised, so that E falls back, and the current is at once re-established. These alternations go on as long as the current is allowed to flow. The difference between the mercury interrupter and any form of mechanical interrupter is one of mechanism, the result being the same with all, *i.e.* interruption of the flow of current in the primary leading to induced high-tension current in the secondary.

degree. The pressure of gas in the tube varies ; the higher it is, the less the potential required to work the X-ray tube and the less penetrating the X-rays. The term soft is applied to a tube when the pressure of gas is high (*i.e.* the vacuum is low), and also to the rays emitted from the tube.

When the pressure is low (*i.e.* high vacuum) the tube is recognised as "hard," and the rays are correspondingly "hard."

It is readily seen, then, that the difficulties in producing results and in repeating them indefinitely are largely due to the variations in the pressure of the gas in the tube.

If the principle of the exhaustion of the X-ray bulb and the method employed for the regulation of the gas pressure are fully grasped, the beginner will be in a position to understand the ruling factor in X-ray work. The manner in which these difficulties when encountered may be overcome falls naturally into the later parts of this work.

The methods employed for the production of X-rays are explained in succeeding chapters, but for introductory purposes it will be well briefly to consider the general scheme by which electrical energy is used, and to illustrate by the diagram on page 4 the arrangement of apparatus common to an X-ray outfit. Special points in construction will not be dealt with.

Source of electrical energy :

A. (1) Battery (a number of cells).
   (2) Accumulators (charged from a dynamo, etc.).
   (3) Direct from a dynamo.
   (4) Upon the current supply of the district.
      (*a*) Continuous.
      (*b*) Alternating. } Voltage should be ascertained and, when the alternating current is used, periodicity also.

The current from any of these sources is led to a high potential generator which may be one of several.

B. (1) Influence Machine.
   (2) Induction Coil.
   (3) Step-up Transformer.

From the terminals of the generator the current is led to the X-ray bulb; several pieces of accessory apparatus are used in the circuit, and, for convenience of handling, the various switches for controlling the source of supply, rheostats, etc., are brought to a switchboard conveniently placed for the operator; when complex interrupters are used the switches controlling the component parts are also placed on the switchboard, so that the operator may be able to control all from one position. These points are fully entered into in the sections devoted to special types of apparatus: the following scheme is based on the arrangement when an induction coil is used as the medium of transformation.

Before discussing the sources of electric energy there are a number of well recognised terms used in electrical practice with which it will repay the beginner to familiarise himself. In the absence of an electrical training he can understand the principles upon which his work is based by studying the elementary works on these subjects, in conjunction with a practical investigation of the mechanical details of his apparatus, and he will then find that many of the most obscure points become clear. A good deal of time devoted to mechanical details and the working of the apparatus will enable him on occasion to remedy a fault which might, if undetected, lead to serious damage to the apparatus and endless trouble to the operator.

Energy of an Electrical Current.—For the purpose of explanation it is usual to compare the passage of an electric current to the flow of water through a hydraulic main. For practical purposes of illustration the analogy is convenient, as it enables us to grasp the meaning and magnitude of electric units.

To calculate the power at any point in a hydraulic main, two figures must be known, (1) the pressure of the water at a given point, and (2) the quantity of water flowing past it per minute. If these quantities are known it is easy to calculate the power. It is necessary to multiply the height in feet of a column of water which would produce the pressure by the number of pounds of water passing per minute ; the figure so obtained is the number of foot-pounds of energy, or work, flowing per minute, and if the figure is divided by 33,000 (the number of foot-pounds in one horse-power per minute), the work is expressed in horse-power.

The energy of an electrical current may similarly be expressed, if the electrical pressure, or difference of potential between the two ends of the circuit and the quantity of electricity passing in it, are known.

The Volt.—The practical unit of electromotive force (EMF) which would cause a current of one ampere to flow through a resistance of one ohm. It is sufficient to define it as the electrical pressure or difference of potential which will produce a certain effect upon a standard instrument kept by the Board of Trade=*Board of Trade Unit.*

The Ampere.—The unit of electrical current is that amount of current which will produce a certain chemical effect in one second. It is also defined as the unit of strength of the electric current, exerted by an electromotive force of one volt through a resistance of one ohm.

The Watt.—Unit of electrical force or energy. It is equal to one volt multiplied by one ampere, and is the work done in one second by a current of one ampere flowing with a pressure of one volt.

Electrical Horse-power.—"Power" is not simply energy or work but the rate at which work is done ; one horse-power as applied to a steam engine means 33,000 foot-pounds of work done in one minute. If the value of a watt can be expressed in foot-pounds the power of an electrical current can be expressed. It may be stated that 746 watts equal 550 foot-pounds in one second, *i.e.* is equal to 33,000 foot-pounds in one minute ; hence it is equal to one horse-power. Seven hundred and forty-six watts is often defined as an electrical horse-power.

It is the same as the horse-power used to measure the work of a steam engine, except that in relation to the steam engine it is customary to express the figure as 33,000 foot-pounds per minute, whereas in electrical practice it is expressed as 746 watts (550 foot-pounds) per second ; the values are the same. Since the number of amperes multiplied by the number of volts gives the number of watts, and 746 watts equals one horse-power, therefore the horse-power of any generator or motor is easily determined by multiplying the amperes and volts together and dividing by 746.

For example, a generator is supplying 500 amperes of current at 400 volts ; this would be equivalent to $\frac{500 \times 400}{746} = 268$ horse-power. Two other commercial units are often employed, namely the kilowatt and the Board of Trade Unit.

The *Kilowatt* is equal to 1000 watts, and since 746 watts = one horse-power, therefore one kilowatt (1000 watts) = $1\frac{1}{3}$ horse-power.

The term kilowatt (KW) is often termed a unit when used to express the size of generators or motors. For example, a 10-unit generator means one which will give an electrical output of 10 kilowatts, a 10-unit motor one which would take 10 kilowatts of current to drive it at full load.

The Board of Trade Unit or kilowatt-hour is the unit generally employed for the sale of electrical current, and is the equivalent of $1\frac{1}{3}$ horse-power per hour.

The Ohm—the unit of electrical resistance employed for measuring the resistance of metals or conductors used for carrying the electrical current. It may be defined as the resistance between the copper terminals of a standard instrument at the Board of Trade.

The Megohm=1,000,000 ohms.—This is simply a larger unit obtained by multiplying the ohm by 1,000,000 for convenience in measuring the electrical resistance of non-conducting or insulating materials.

Ohm's Law, named after its discoverer. It is used to define the relation between the quantity of current, the electromotive force (potential, or pressure), and the resistance in a circuit.

This law states that the strength of a current flowing in an electrical circuit is directly proportional to the difference of potential, or pressure, at the ends of the conductor, and inversely proportional to the resistance of the conductor.

It may be conveniently expressed in symbols :

If C=Current (amperes),
E=Electromotive force, difference of potentials, or pressure (volts).
R=Resistance (ohms),

then Ohm's Law states that $C=\frac{E}{R}$.

This statement may be expressed in several ways, thus :

$$C=\frac{E}{R}. \quad (1)$$

$$R=\frac{E}{C}. \quad (2)$$

$$E=CR. \quad (3)$$

These are equivalent statements of Ohm's Law and can be expressed in words :

(1) Current equals electromotive force divided by resistance.
(2) Resistance equals electromotive force divided by current.
(3) Electromotive force equals current multiplied by resistance.

PART I.—RADIOGRAPHY

SOURCES OF ELECTRIC ENERGY

Continuous Current Supply

The most efficient and the most convenient form of electric supply is the continuous current, because it can be used without any alteration or modification for all types of interrupters. For mercury interrupters provision should be made for a current supply of up to 12 amperes, for electrolytic interrupters up to 20 amperes or more. These currents will suffice for an ordinary installation where very rapid exposures are not necessary. When wiring for an installation it is always advisable to have installed wires of larger capacity than the actually required amperage, for we may at a later date require a larger current for a more powerful outfit, which, to operate to its full output, may require up to 50 amperes. The tendency is to increase the current-consuming capacity of the apparatus—single-flash outfits, Snook apparatus, and other forms of modern high-tension transformers capable of using for an instantaneous exposure from 60 to 100 amperes in the primary.

When arranging for a current supply for one of these outfits it is well to provide for 100 or more ampere-circuit, in order that the operator need have no fear of either overloading the main cables or blowing the main fuses.

The main fuses of such installations should be in an accessible position, and it is well to have a supply of fuse wire near at hand, and when large fuse cartridges are used a number of spare fuses should always be kept ready for use. Much annoyance from delay may thus be avoided. It is of the greatest practical value to have, instead of the ordinary wall plug, a double-pole switch and two single-pole cut-outs enclosed in a lock-up case fitted on the wall of the radiographic room. In this way the switch and fuses are always accessible, and in addition it is possible by opening the switch to isolate all the apparatus from the supply mains.

Alternating Current Supply

There are several combinations of apparatus which may be adapted to an alternating current supply. Of these the following are the most commonly used. (1) An independent motor transformer to change the current into a continuous one from which a coil outfit may be worked. (2) High-tension rectifier. (3) A coil working from the mains by means of an alternating current break; the latter method is useful under favourable conditions. (4) By means of a cell rectifier in conjunction with a Wehnelt interrupter.

If the supply is an alternating current with a periodicity of 40 to 60, and the X-rays are not needed for very short exposures, it may be coupled directly to some types of mechanical interrupters. One of the most useful types of installation for alternating current is a Gaiffe Rochefort transformer with a Gaiffe gas mercury interrupter. Very good work may be done with this apparatus, and the only difficulty occurs in the starting of the interrupter; the motor has to synchronise with the periodicity of the supply, and it requires a little practice to enable the operator to overcome this initial difficulty.

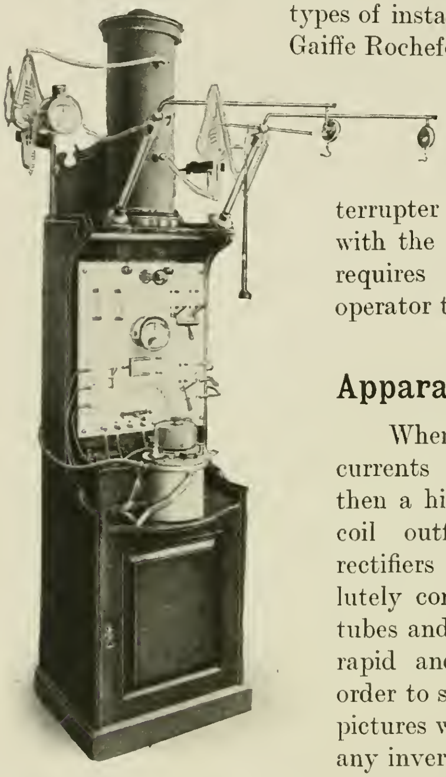


FIG. 2.—Outfit for alternating or continuous current. For alternating supply there is a difference in the arrangement of the interrupter. (Medical Supply Association.)

Apparatus for Heavy Discharges

When it is necessary to use heavy currents for instantaneous radiography then a high-tension rectifier or a powerful coil outfit is necessary. High-tension rectifiers are designed for generating absolutely continuous current impulses for the tubes and for producing large outputs for rapid and instantaneous radiography, in order to secure good radiographs and screen pictures without at the same time producing any inverse radiation.

The principle of such an apparatus is as follows: Alternating current is stepped up by means of a high-tension transformer to the pressure necessary to stimulate an X-ray tube, but as continuous current is essential, the high-tension alternating current is converted into a pulsating continuous current by means of a synchronous rectifier.

The chief factor is therefore a high-tension rectifier which is designed on the principle of the well-known commutator employed for dynamos and motors. This rectifier is coupled mechanically and electrically with the motor, alternating in such a manner that commutation takes place in synchronism with the frequency of the alternating current. For instance, if alternating current is available having a frequency of 50 cycles per second, the rectifier will give, in the same time, one hundred continuous current impulses, or expressed scientifically, the rectifier is in synchronism with the alternating current.

The commutation of the rectifier always occurs at the moment when the alternating current is at zero value, that is, at the moment of the change of direction. When working accurately this arrangement practically prevents the generation of inverse current which is so harmful to the tubes.

Synchronism is obtained simply and absolutely by employing a rotary converter which is connected to a continuous supply, and which at the same time supplies the alternating current to the transformer and rotates the rectifier which is mounted on the same shaft.

Alternating Current High-tension Rectifier.—When using the alternating current, the current for the transformer is derived direct from the supply, the rectifier being driven by a self-starting single-phase synchronous motor which takes the place of the converter.

The outfits made for alternating current are smaller than for continuous, and these small outfits are without doubt the best to use where ordinary X-ray work only is required (*i.e.* not instantaneous work), as there is no trouble from inverse radiation, no interrupter to synchronise, no rectifier to attend to, and no expensive rotary converter required.

Accumulators

If no current from a main is available, accumulators may be used provided there is an opportunity of getting them recharged easily; but it must be understood that the time of exposure required will be much longer, because with twelve 2-volt accumulators we cannot produce the same intense discharge which can be produced with a 100- or 200-volt supply. If there

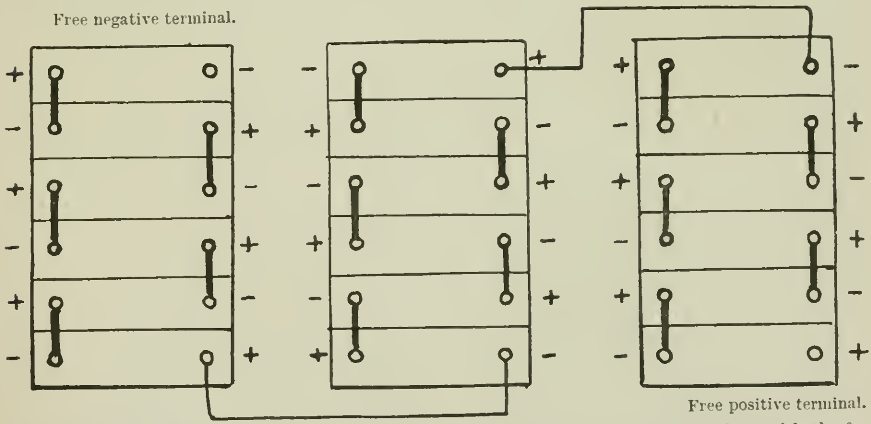


Fig. 3.—Accumulator connections. The positive wire going to the coil is connected up with the free positive terminal of the accumulators, and the negative wire with the free negative terminal.

is no facility for recharging the accumulators, twelve or more large bichromate cells may be used; but if the apparatus is required for use frequently, the recharging of bichromate cells is troublesome. In such circumstances other methods of obtaining a supply of current must be adopted, such as the use of a small gas engine and dynamo.

Accumulators may be used alone or in conjunction with a dynamo;

in the former instance they require to be charged from time to time either from the lighting or power circuit through a charging board, or they have to be taken to the power station for recharging. The latter procedure is not at all convenient. When accumulators are used, it is well to have a dynamo to charge them ; this may be more convenient than the installation of a large dynamo from which the current is obtained to stimulate the coil. A comparatively small dynamo may be used to charge the accumulators when a low amperage may be used. The number and size of the accumulators will determine the amperage it is possible to use for the coil. A sufficient number of accumulators will give a greater amperage for a short time than it is possible to obtain from the charging dynamo.

When a dynamo is used for the working of the coil it is, of course, necessary that it should run during the time the coil is used. It is not able to stand the demands of very heavy amperage for rapid exposures. When accumulators are used they may be charged at any time, but the use of the dynamo is not necessary when the accumulators are in use. In small rooms this is an obvious point in favour of accumulators, for the dynamo is at the best of times rather noisy when working.

It follows that when the current has to be produced by the use of a dynamo a large set of accumulators will facilitate easy working, and they may be arranged to give almost any amperage required for rapid radiography. The operator is in this way quite independent of the modern power station, which cannot always be depended upon.

A practical point of some importance in the use of accumulators is to see that they are kept well charged and ready for use. It is also well to remember the mode of connection to the coil and break. The diagram on p. 13 illustrates this point.

Dynamos

A gas or oil engine can be used to drive a small dynamo. The oil motors

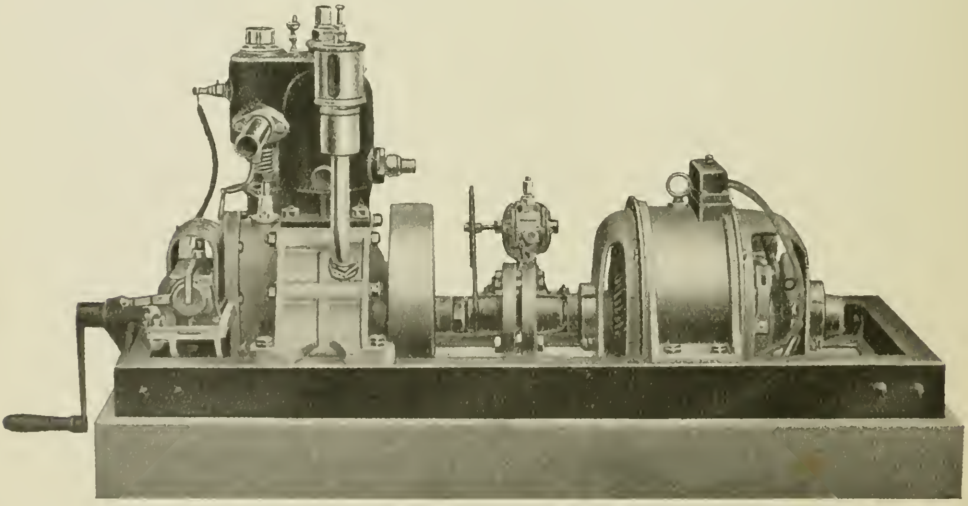


Fig. 4.—Gas Engine and Dynamo. Generator set with petrol engine. (Siemens.)

are similar to those used in automobiles; they can be easily started, are small and portable.

The term dynamo is often applied to a machine in which mechanical energy is changed into electrical energy. It is more accurate to use the term generator. A machine in which electrical energy is converted into mechanical energy is more accurately designated a motor. The word dynamo is equally applicable to both generator and motor.

It is hardly necessary to go into details of these outfits, as the occasion for their use is rarely likely to occur except in remote country districts, or for military purposes.

Motor Transformers

These transform the alternating current into a continuous one, a motor driven by an alternating current being coupled to a dynamo which delivers a continuous current. The size ought to be chosen so that at least 1000 to 2000 watts can be obtained from the dynamo. These motor transformers are very reliable, easy to work, and require scarcely any attention. The motor transformer should be placed on a solid bed-plate and well away from the X-ray room, as the noise they make is a constant source of annoyance to the operator.

The motor transformer, when used to transform the alternating into a continuous current, supplies the coil which has to transform the low-tension current into one of high tension.

The transformers most generally used for this purpose are induction coils, and these will be considered first, though the tendency is increasing to use high-tension rectifiers for the production of powerful currents. These will be considered later. The necessary current may also be produced by means of the static machine. A large Wimshurst machine will produce enough current to work an X-ray tube.

The need for portable outfits in connection with the war has led to a great development in the provision of motor wagons containing complete X-ray apparatus, with all accessories. The mechanism used for driving the wagon, *i.e.* the motor, is coupled with a powerful dynamo which delivers a continuous current.

Methods employed for the Transformation of a Low-tension into a High-tension Current.—Having briefly considered the sources of electric current, the next step is to follow the process of utilising the current we have at hand, which is a low-tension one and useless for the stimulation of an X-ray bulb. Owing to the high resistance of such a tube the 100 to 250 volt-currents supplied on most mains cannot find a path through it.

The construction of the X-ray bulb is such that the current has to overcome a very high resistance between the two terminals, and it is necessary to have a high tension of 100,000 volts or more to do this. The low-tension current can, however, be converted into a high-tension one by transformation. A low-tension current of 100 volts may be readily changed into one of 100,000 by means of such a transformer.

The high potential current necessary for the stimulation of the X-ray bulb may be produced in a number of ways. Of these the most usual are: (1) Influence machines, such as the well-known Wimshurst or Hultst machines. (2) Induction coils. (3) Step-up transformers.

Influence Machines

The type most commonly used is the Wimshurst; it is largely employed in France and in the United States, but has not found much favour in this country, probably owing to climatic reasons. The machine works best in a dry climate, though even in a humid one arrangements may be made to overcome the difficulty.

With a multiple-plate machine in good working order a steady X-ray discharge can be obtained. The current is unidirectional, and is not so destructive to the anti-cathode as pulsating or alternating. The voltage obtained from a Wimshurst machine is proportional to the speed of the plates.

The Induction Coil

The essential parts of an induction coil are:

(*a*) The Core.
(*b*) The Primary.
(*c*) The Secondary.
(*d*) A condenser is necessary when a mercury interrupter is used.

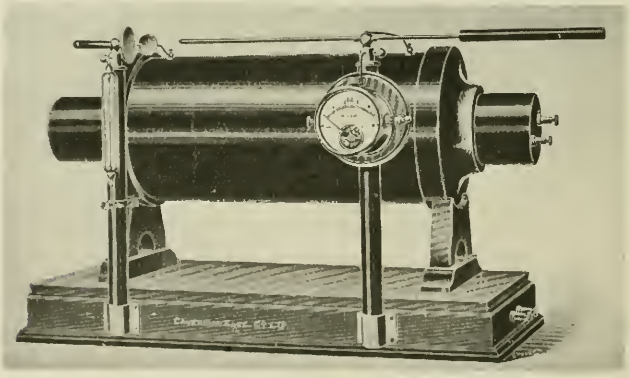


Fig. 5.—Induction coil. (Cavendish Electrical Co.)

The Core.—In order to get the maximum of efficiency from the induction coil the aim is to magnetise the core slowly (at make), and demagnetise it rapidly (at break), the spark length depending upon the rapidity with which the core can be magnetised, the output of the coil upon the degree of magnetisation.

The size of the core depends upon the size of the primary and the current passing through it, and on the frequency and character of the break and the output arranged for.

The modern heavy discharge coil has a very large and stout iron core, generally made up of sheets of metal, whose length is five or six times its diameter or even more.

The chief objects in core design are, (*a*) to diminish the inverse current, and (*b*) to reduce the losses due to "eddy currents." The inverse current is lessened by packing as much iron as possible into the space allowed for the core. "Eddy currents" are reduced by using, instead of a solid iron core, packed wires or plates varnished to diminish the electrical contact between them.

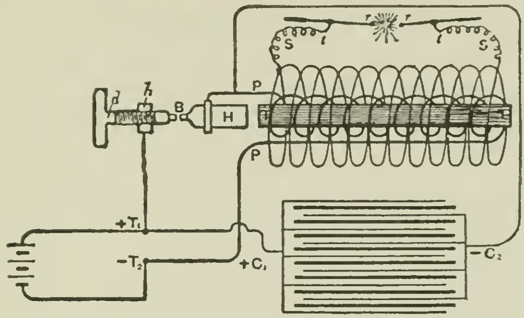


FIG. 6.—Plan of winding of coil (primary, secondary), and connection to condenser and break. (Newton & Wright.)

The Primary.—The primary consists of a number of turns of a thick copper wire wound round the core. The primary coil is usually wound in three layers, either as a simple winding, or, as is more common, as an adjustable winding to allow of adaptability to meet prevailing conditions.

Three methods of winding the primary are employed :

(1) The connections are so arranged that each of the three layers can be put in series or parallel with the others. These are connected up to terminals at one end of the coil and serve to vary the quantity of current in the primary. They may be wired up to a switch-table and controlled from there, so that the operator may select the winding most suitable for the work required.

(2) The winding is arranged so that the coils can be tapped to permit connection with different parts of the primary circuit.

(3) The primary is wound with several wires arranged so that these multiple windings can be put either in parallel or series at will.

The object of dividing the primary coil is in order to change the self-induction.

The primary is placed in an ebonite tube to insulate it from the secondary coil.

The Secondary Coil consists of many thousand turns of fine calibre wire wound in a number of thin vertical sections. The diagrammatic representation above will best show the connections of the primary, secondary, condenser, and interrupter of an induction coil.

T (Fig. 6) represents the iron core, P the primary or thick copper winding, P and T together forming the electro-magnet. SS is the thin or secondary winding.

In nearly all modern large coils the secondary is now wound in a number of flat sections separate from end to end, each section insulated from the next by a partition of some non-conducting material, the sections being joined together alternately by their inner and outer windings, so as to form one continuous helix the whole length of the coil.[1]

Between the secondary SS and the primary winding PP is the insulating or primary tube, not shown in the diagram.

Method of Action

B represents the simplest pattern of contact breaker. This form is used for convenience of illustration ; it is never used in modern coil outfits for radiographic work.

H is a piece of soft iron carried on a stiff brass spring, which is pulled towards the magnet T whenever the latter is magnetised.

B is a pair of platinum-tipped contacts, the front piece attached to the brass spring and iron pole piece H, the back one brazed to an adjoining screw *d*, working in a collar *h*, so that the distance between the platinum tips can readily be adjusted.

The current is passed from the positive pole of battery or mains into the adjusting screw *d*, thence through the platinum contacts B, the primary winding PP, thence back to the negative pole T_2. The circuit being completed, the core T becomes magnetised, the iron hammer H is attracted, and the platinum contacts are pulled apart, thus breaking the circuit.

The core thereby becoming demagnetised, the platinum contacts are

[1] The most common form of sectional winding is illustrated in the accompanying figure, the ends of the sections being joined together alternately at the inside and the outside. Between each section is a layer of some insulating medium, usually waxed or varnished paper, the thickness of which must be sufficient to stand the tension between the inner and outer edges of the sections, a pair of sections joined together in the inside having considerable difference of tension at their outer edges and *vice versa*.

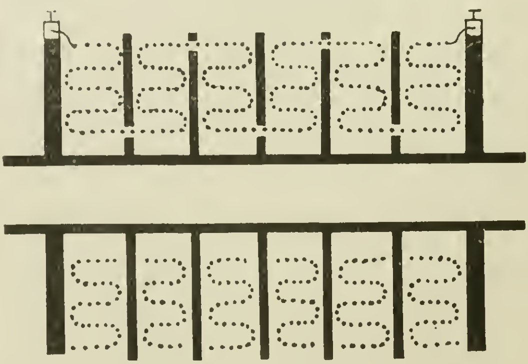


Fig. 7.—Diagram of sectional winding of secondary coil. (R. S. Wright, A.M.I.E.E.)

pulled together again by means of the brass spring, and contact is again made, and the core T again magnetised, and so on. C is the condenser, the thin lines representing leaves of tin-foil, the thick ones insulating partitions of waxed or varnished paper.

When the contact at B is broken, the current passes into one side of the condenser at C, and by providing this alternative path the necessary sparking at B is greatly reduced, and, what is of much greater consequence, the suddenness of the break, and therefore the speed at which the core becomes demagnetised, is greatly increased.

The electric motive force or spark length increases with the number of turns of the secondary winding.

By choosing the number of turns it is possible to transform a primary current of 200 volts to 50,000 or 100,000, but the number of amperes is reduced in the same proportion because, though the numbers of the volts and amperes can be changed by transformation, the total energy can never be increased.

If the transformation could be effected without loss, a current of, say, 200 volts and 10 amperes could be transformed into 50,000 and 40 milliamperes ; but as losses occur in every transformation of energy by friction, radiation, and conversion into heat, the current obtained under the above conditions will be between 25 and 30 milliamperes instead of reaching to 40 milliamperes.

To overcome the resistance of an air-gap of

4 inches	8 inches	12 inches	16 inches
110,000	150,000	190,000	230,000 volts

are necessary.

The Condenser

Most of the coils constructed up to quite recent times were fitted with condensers ; the description of the working of the coil shows that the condenser is a necessary addition to the coil outfit when it is worked under special conditions.

It is absolutely necessary when the mercury interrupter is used ; it is then connected in parallel with the interrupter, helping to reduce the spark appearing in the interrupter on breaking the primary current, and to demagnetise the iron core quickly.

It is quite unnecessary when the electrolytic interrupter is used, and, as Lord Rayleigh has shown, it may be dispensed with when using a mercury interrupter if the primary current is interrupted with sufficient rapidity. *Vide* his experiments in severing a wire with a rifle bullet.

A brief consideration of the construction and uses of a condenser will enable us to understand its action.

The condenser consists of a number of sheets of tin-foil which are insulated from one another by sheets of waxed paper, the condenser being usually enclosed in the base of the coil. When it is placed thus the author usually insists on having two condensers connected to each coil in order to avoid delay, as, should one become pierced, the other can quickly be connected up and work go on at once. This is rather an important point when a considerable amount of work has to be done. The condensers should be placed in an easily accessible position to avoid delay in changing when one goes out of order, and there is no reason, save that of convenience, why it should be placed in an inaccessible position.

The functions of the condenser are three in number :

(1) To increase the slowness of the " make " and the suddenness of the " break."

(2) To suppress undue sparking and " arcing " in the interrupter.

(3) To retard the formation of induced currents in the primary.

It is important that the capacity of the condenser should be as nearly as possible adapted to the particular value of the inductance of the primary as well as to the magnitude and frequency of the primary current. The capacity required also depends considerably on the type of interrupter ; therefore an adjustable condenser should be used when a coil is required for a variety of purposes.

The induction coil at the present time is generally used with a mercury or Wehnelt interrupter. Of the first mentioned, there are several very efficient interrupters obtainable which give large outputs with the coil.

The Wehnelt interrupter can be arranged in a number of variations of coil and interrupter according to the primary winding and the number of points in the interrupter. These allow of moderately rapid exposures being given, but if instantaneous exposures are required of about $\frac{1}{100}$th of a second, then the long specially wound coils with special single impulse switch must be used. The form of switch or interrupter employed is also variable. The radiographs taken with this form of apparatus are very sharp and well defined ; the single-impulse switch is also readily adapted to the high-tension transformer. When used for single-impulse work only with an ordinary or Coolidge tube this type of coil is probably the most efficient at present in use ; it is an ideal apparatus for utilising the potentialities of the Coolidge tube, because of the ready adjustments of this tube to conditions most suitable to the coil.

In the apparatus designed by Morton (see Therapeutic section) the inverse current is banished ; in that of Mackenzie Davidson it is utilised by passing it through the tube in the right direction by an ingenious piece of apparatus. Gunstone has devised a method for attaining the same end in a somewhat different manner.

It is not generally realised that the same coil cannot be equally efficient for all purposes. It cannot prove equally satisfactory for hard and soft bulbs, or for various combinations of interrupter. A typical example of this is found in the large coils constructed for single-impulse exposures ; these, when working on the single-impulse switch, give beautiful radiographs of the thorax or the abdomen, but when used on the Wehnelt or mercury interrupter the results are not nearly so good, even when the difference in the exposure is allowed for. A practical conclusion arrived at from a considerable experience of all types of coil is that it is far better to have several coils built for special purposes than to endeavour to achieve with one coil the same results under varying conditions of interrupter. The coils can be wound to suit the special requirements.

If this plan is followed, greater efficiency in all classes of work will be attained.

Practical Points in Coil Construction and Design

Kaye, in his book on X-rays, calls attention to the following points: The chief objection to the Induction Coil for X-ray work is the inverse current which all coils generate at "make," and also to some extent at "break."

There are a number of ways in which this inverse current may be minimised, and, according to some manufacturers of apparatus, abolished altogether; when present to any extent it may be modified by:

(1) Making the number of turns in the primary as long as possible.

(2) By reducing the magnetic leakage between the primary and secondary.

Irregular working of the interrupter may also be a contributory cause to the appearance of inverse current; great attention should therefore be paid to this part of the apparatus. Sparking, when it appears in the interrupter, may be minimised by reducing the frequency of the interruptions. But when all possible precautions for the suppression of inverse current have been taken it frequently manifests itself, and is a source of constant annoyance to the radiographer.

Several methods other than those described in "coil construction" have been adopted for the suppression of inverse current.

(*a*) One or more valve tubes may be employed; these are useful, but require almost as much care as the X-ray bulb, if they are to be kept in working order.

(*b*) The employment of a rectifying device on the interrupter—Morton, Mackenzie Davidson, and others.

Sparking Pillars.—Coils are provided with sparking pillars. One of these has usually a point, while the other is provided with a plate. This arrangement is useful for the detection of the polarity. The sparks will discharge easily from the point to any part of the plate when the latter is the negative pole, as shown in Fig. 8, page 22.

When the point is the negative pole the sparks will discharge from the edge of the plate to the point, as shown in Fig. 9, because the discharge would then be easier than from point to plate.

When a current is sent through the primary winding the iron core becomes magnetised and a magnetic field is created.

The appearance or disappearance of the field, or any variation in its intensity, induces currents of short duration in the secondary coil, their intensity depending on the intensity of the magnetic field, and the suddenness of its appearance or disappearance.

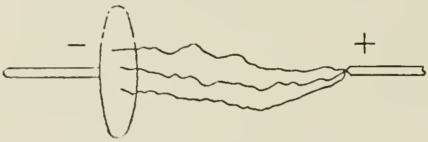


Fig. 8.—Connections of the X-Ray tube to the coil, showing the route travelled by the sparks when the point is the positive pole and the negative the plate.

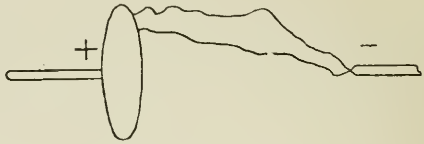


Fig. 9.—Connections of the X-Ray tube to the coil, showing the appearance when the poles are reversed.

To obtain X-rays of sufficient intensity for short exposures powerful coils have to be used. With such powerful discharges as are necessary for present-day work in hospitals and private practice, it is much better to duplicate installations in order that the various exposures required for radiography and therapeutic purposes may be independently obtained to the best advantage. A coil outfit capable of giving instantaneous exposures is much too wasteful to use for the smaller discharges required for therapeutics, and when an attempt is made to combine the component parts of the installation so as to give these requirements from one and the same apparatus, something must be sacrificed, and no doubt this fact explains a good deal of the trouble that is experienced when using one installation for all purposes. A large outfit should be reserved for the radiographic work, a less powerful one for therapeutic work.

The Control Apparatus

It is necessary to be able to control the supply current; for this purpose a two-pole cut-out switch is introduced at a convenient part of the room. This controls the supply from the mains.

For the convenient control of the coil and interrupters, a switchboard or switch-table of some form is a necessity. This consists of marble or slate panels on which are mounted a main switch to turn the current on and off, and a variable resistance to control the intensity of the current.

In most cases the switchboard is provided with voltmeter and amperemeter to measure the primary current, with a switch and rheostat to control the motor of the interrupter, a signal lamp to indicate whether they are turned on or off, and the necessary fuses and terminals.

In more elaborate installations the switchboard may be provided with a switch to allow the use of either a mercury or electrolytic interrupter, and the use of the anodes of the latter separately or connected in parallel; with a switch to change the self-induction of the primary coil; and with an automatic switch and time relay to break the primary current automatically after setting to a fixed time which can be varied from 0·05 to 10 seconds.

Single-impulse and similar forms of apparatus require a special automatic switch for use when giving the most rapid exposures.

The next point to consider at length is the question of the use of a rheostat, an instrument which enables us to vary the current supply to the primary coil.

Two forms of rheostat may be used, and it will be well to consider each in detail, as a clear knowledge of their use may prevent the operator from making mistakes, the cause of which he may have difficulty in understanding.

When using a series rheostat the full voltage of the supply is reduced to a very small extent, whereas by means of a shunt rheostat the voltage can be reduced and varied gradually.

This latter form has decided advantages if moderate or low pressures are required, because the variable voltage gives a better control over the discharge. With a shunt resistance the discharge can be varied in wide limits, and it can be better adapted to medium and soft tubes than is possible with the series connection.

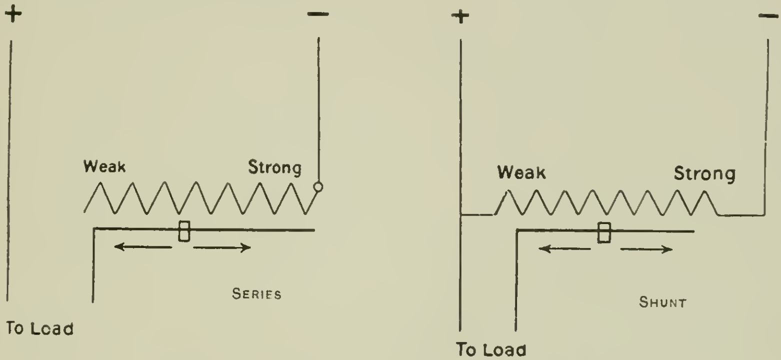


Fig. 10.—Diagrams of rheostats. (By permission of Messrs. Watson & Sons.)

As the amount of reverse current generated is in direct ratio to the voltage used in the primary coil, less reverse current is obtained with the lower voltage available with a shunt than with the higher voltage which is inseparable from the series connection. The tubes have, therefore, a longer life when used with the shunt connection, which is consequently more economical and to be preferred for all time exposures and for therapeutic purposes, or, in other words, whenever moderate or weak currents have to be used for a comparatively long time.

When short exposures are necessary the effects on the tubes must be to a large extent neglected, and the full voltage of the mains used, so that a larger milliamperage can be obtained in the tube circuit, and in all such cases the series connection with little or no resistance in the circuit is better than the shunt connection.

The objection to shunt rheostats is that they are wasteful, and more expensive, but after all the cost of electrical current is much less than that of tubes. A complete switchboard should, therefore, have both methods of control.

It should be noted that authorities do not agree entirely with the statements of comparison between the two forms of rheostats. A good deal depends upon the construction of the coil and the interrupter, and the accuracy with which they are adjusted to one another. Other factors may also influence the degree of inverse current produced.

The Interrupter

This important part of an X-ray outfit requires a lengthy consideration, and it will well repay the beginner to familiarise himself thoroughly with this part of his installation. He must know its construction, how to regulate it, and above all how to clean it when necessary. The interrupter serves the purpose of closing and opening the primary circuit. It should keep the primary current closed long enough to allow the iron core to reach the maximum magnetisation. The sharper the opening of the primary circuit, the higher will be the tension of the secondary current—the opening induction current—and the greater therefore is the discharge.

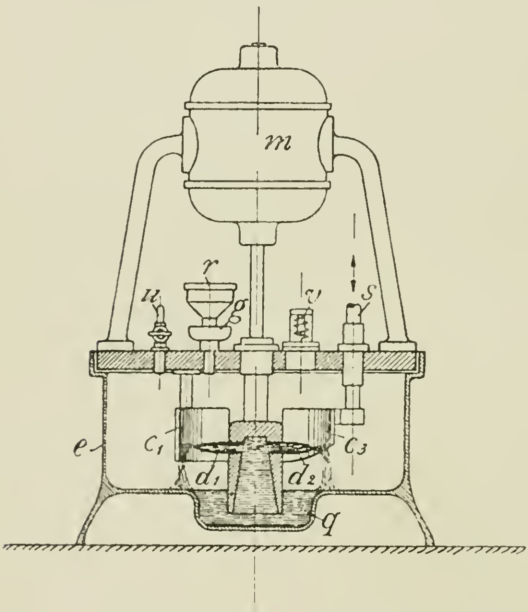


Fig. 11.—Diagram to illustrate construction of a centrifugal mercury interrupter. (Siemens.)

m, Motor.
c^1 and c^3, Contacts.
d^1 and d^2, Mercury jets.
q, Mercury.
s, Adjustable contact.
r, Funnel for di-electric.
v, Safety valve.
u, Gas tap.
e, Containing vessel.
g, Closing valve.

For practical purposes there are two types of interrupters which require description. These are:

(*a*) The Mercury Interrupter.

(*b*) The Electrolytic Interrupter.

Of the former there are many varieties, but it will suffice to mention a few and give a short description of each before proceeding to the electrolytic type. The mercury interrupters may be classified in three groups:

(1) Dipper, Mackenzie Davidson type.

(2) Rotary, Cavendish.

(3) Jet, Dreadnought, Instanta, and others.

Probably the best all-round interrupter of the centrifugal mercury type is that now known as the Cavendish, but this has one objectionable feature, viz. the trouble of cleaning it. The undoubted advantage which other forms of mercury interrupters possess over it is the ease with which they may be cleaned, and owing to the fact that gas is used in many as the dielectric instead of paraffin they require cleaning less frequently, and, further, the mercury never becomes emulsified. Practically every maker manufactures an interrupter of the mercury jet type, and a general description will apply to all. The principle is the same in each—a mercury jet rotating in a vessel with a gas or liquid di-electric. The gas supply may be obtained direct from the mains, or a large rubber bag may be inflated with gas and attached to the tap on the interrupter. Fig. 11 illustrates the chief points of a mercury interrupter, and Fig. 12 illustrates the action.

On reference to the diagram it will be observed that two contacts, C1 and C2, are both connected to the common terminal D. This terminal is connected with one of the supply wires. One of the remaining terminals, say E, is then connected to the induction coil, and the other terminal of the induction coil connected back to the supply.

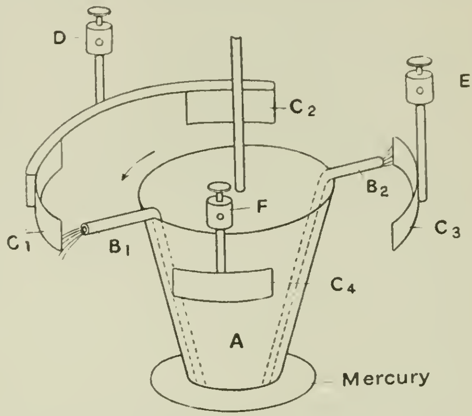


FIG. 12.—Diagram illustrating the action of a centrifugal mercury interrupter.

When the jets B1 and B2 are in the position shown the current will enter D and will pass from contact C1 by way of the jet, down the tubes of the pump A, out again to the jet B2, on to contact C3, and thence through the induction coil and back to the supply.

The diagram shows the pump in such a position that the current is just about to be broken as the jet leaves the contacts C1 and C3.

If the terminals E and F are externally connected, it will be noted that the frequency of interruption will be doubled as current will also pass between C2 and C4 when the jets are in that position.

Dreadnought Interrupter.—This interrupter consists of two parts: the interrupter proper and the motor for driving it. The latter is usually mounted on the top of the interrupter and can be removed by unscrewing a few milled nuts. The part projecting into the receptacle consists of the rotating jet driven by the motor and the contacts against which the mercury jet impinges. The revolving disc with the jets make and break the contact two or four times per revolution, according to the number of contacts in action at the time. The required amount of mercury is poured into the vessel and the top replaced and refixed. The interrupter is then connected to the coil and condenser and the motor to the supply mains (see Fig. 15). Most of these interrupters are provided with an arrangement of contacts and terminals, so that it is possible to double the number of primary interruptions, and so increase the effect in the secondary or tube circuit; other types have an adjustable wedge-shaped contact. Great attention should be

FIG. 13.—Dreadnought interrupter.

paid to the cleanliness not only of the interrupter but also of the motor, and especially of the commutator and oil cups. To fill the interrupter with gas, one tap is connected to the gas supply by a rubber tube and the other tap is left open for a few moments in order to expel the air. The gas jet may be ignited and allowed to burn until all air has been expelled This is

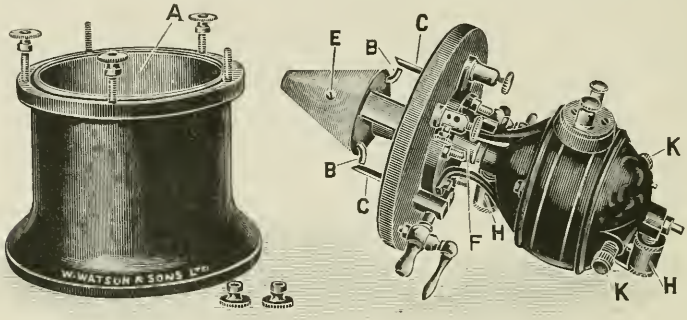


FIG. 14.—Dreadnought interrupter showing detail.

A, Container.
B, Jet.
C, Contact teeth.
E, Screw.
F, Shaft bearing.
H, Oil cups.
K, Motor brushes.

seen to be completely driven out when the flame is yellow in colour. (If air is allowed to remain in the receptacle and the interrupter allowed to rotate, then an explosion takes place which may seriously damage the parts.) This tap is then closed and the other connected to the gas supply left open, and advantage taken of the pressure from the mains. If there is no handy

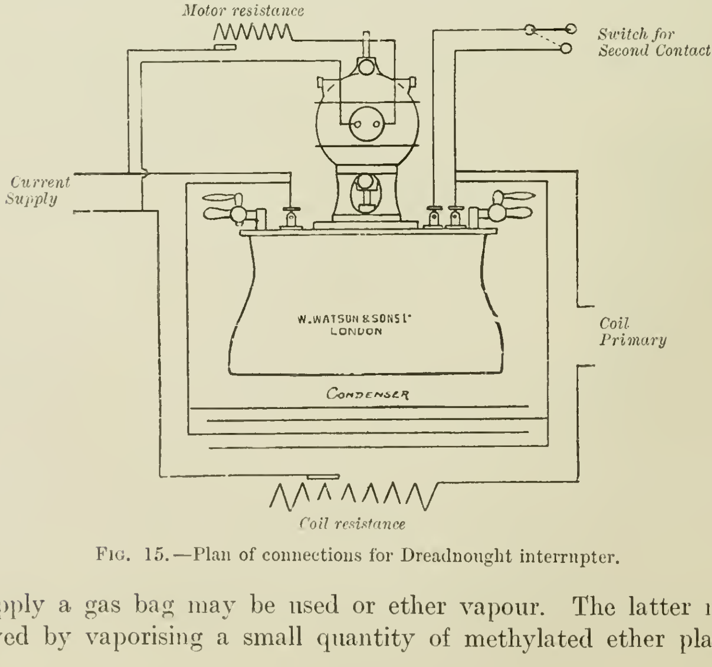


FIG. 15.—Plan of connections for Dreadnought interrupter.

gas supply a gas bag may be used or ether vapour. The latter may be employed by vaporising a small quantity of methylated ether placed on the top of the mercury and starting the interrupter with a small current before closing the taps.

Fig. 15 shows diagrammatically the connections of the motor, interrupter, control for the current passing to the coil, speed regulator for the motor, condenser and primary of the induction coil.

It will be noticed that one wire from the main supply is connected to the common terminal, that is to say, the terminal which supports two contacts. The other wire from the main supply passes through the controlling resistance and primary of the induction coil and back to one of the two remaining terminals on the interrupter lid.

The condenser is connected directly across the two terminals on the interrupter already mentioned. The second contact switch merely connects the two adjacent terminals together, so as to bring into play all the four contacts, thus giving four interruptions per revolution.

If this switch is in the "off" position, as shown on the diagram, only two interruptions per revolution will result.

The resistance for controlling the speed of the motor is, of course, connected in parallel and quite apart from the coil circuit. The paths of the currents inside the interrupter are more clearly shown in Fig. 12. It will be noticed in this diagram that one terminal previously designated "common terminal" supports two contacts, and each of the remaining two support one contact only, and it is left to the second contact switch to connect these last two together when required.

In the **Instanta interrupter** and others there is an arrangement of four jets so that eight makes and breaks are obtained per revolution, and it is also so arranged that the circuit is broken in two different places at the same moment. This has the effect of greatly increasing the suddenness of the interruption.

Centrifugal Motor Mercury Interrupter.—This interrupter consists of a small steel pear-shaped bowl mounted direct to the axle of an electric-motor and situated perpendicularly above the motor. Thus, when the axle of the motor rotates, the pear-shaped bowl is rotated also. Inside the bowl a very small quantity of mercury (only 10 oz. weight) is placed, and, by centrifugal force, travels up the side of the bowl until it finds the extreme periphery, where a distinct groove or bed is made to receive it. Thus it will be seen we have a revolving bowl and in it a revolving ring of mercury. Inside the interrupter bowl and carried on a vertical spindle is a fibre disc with two copper segments. This disc is mounted, free to revolve, on ball-bearings top and bottom, and is horizontal in position. It is not placed in the centre of the bowl, but over to one side, so that when the bowl rotates its edge engages with the rotating ring of mercury and is, therefore, of course, revolved by it. The current is led to the metal bowl and to the mercury ring by means of an ordinary terminal, and the current is led also to the segment in the disc by means of the spindle carrying the latter. Thus, each time one of the copper segments enters into the mercury ring the current is allowed to pass, and each time the segment leaves the mercury ring and the fibre of the disc enters the ring, there is an interruption period.

By the unique construction of working two circles together—the mercury ring and the fibre segmented disc—a splitting up of the mercury, such as would occur by plunging into the mercury any other form of contact, is completely avoided.

As already mentioned, the free revolving fibre disc with two copper segments is placed not in the centre of the bowl but eccentrically, and can be inserted more or less into the mercury ring from the outside, even if the motor is running. This arrangement makes it possible to put the disc so that it just touches the mercury ring, in which case the duration of contact is very short. The further the disc is put into the mercury ring the further the segment travels in the mercury, and therefore the duration of contact can be extended as desired. Moreover, the number of interruptions is regulated by the speed of the motor by a special volt regulator mounted on the switchboard, so that not only is the duration of contact independent of the number of interruptions, but both are also independent of the primary current.

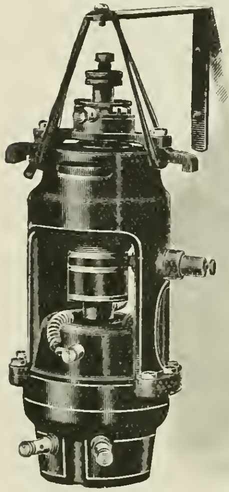


Fig. 16.—Centrifugal motor mercury interrupter. (Cavendish Electrical Co.)

The Di-electric used in this type of interrupter is liquid paraffin. Alcohol, gas, and other di-electrics have been tried, but paraffin has been found to be the most satisfactory.

Before the introduction of this interrupter the mercury interrupters using paraffin as a di-electric, in spite of their numerous advantages, had the great disadvantage of emulsifying the mercury. The cause of this is due to the mechanical breaking up and churning of the mercury with the di-electric. After working the mercury interrupter for a short time it is imperative to remove the dirty mercury and to clean it—a very disagreeable and troublesome proceeding. The ingenious principle of the interrupter—the working together of the two circles in unison and the continuous centrifugal rotation—delays the emulsification of mercury. In consequence of its greater specific weight the mercury is always driven to the farthest outside point and disintegrates by itself all the lighter substances, therefore remaining for a longer or shorter time, according to the amount of usage, clean at the point of interruption.

The Number of Interruptions can be increased up to about 12,000 per minute. By means of a resistance switch on the switchboard the motor can be run fast or slow, and further, it is possible to run the motor at any desired speed, thus obtaining any number of interruptions up to the limit of the mechanism.

Causes of Defective Working.—A few short hints on the causes of defective working may be of assistance to workers. If when switching on the motor it does not start up, the speed regulator should be at once cut out, and then the motor having started, it can be brought back to the position of usual working.

There also may be an interruption or short circuit in the main cable leading to the switchboard or table, or the cables leading to the motor of the interrupter may have become loosened, or the brushes and their screws may have become loose, all of which faults would be indicated by the motor refusing to start. If the commutator starts to spark after running some time it will be found that this is generally due to oil and carbon dust, and this must be removed by cleaning the commutator with fine emery cloth, and also cleaning the carbon brushes. If when the coil is now switched on we observe no light in the X-ray tube, this may be due to the fuse having been burnt through or become loosened. Great care must be taken to see that all bearing contacts are clean, that all cables are perfect, and that all terminals are absolutely secure.

Should the tube give an unsteady fluorescence this may be due to some

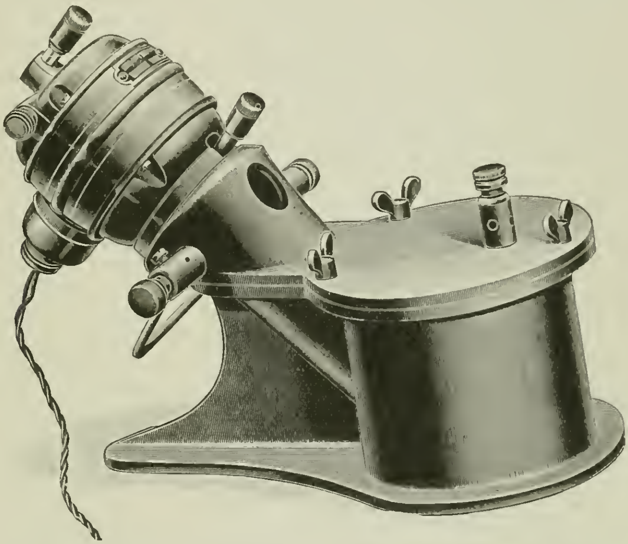


FIG. 17.—Improved Mackenzie Davidson interrupter. (Schall.)

extent to the variation of vacuum, and can be controlled somewhat by adjusting the interrupter. If the tube flickers with a contact of a certain size, it may be steadied by increasing this contact. This flickering may be also due to the motor of the interrupter running slowly. Another reason for this effect in the tube may be the piercing of the condenser, and this can be detected by testing the spark length of the coil. If one cannot obtain the full spark length and the primary current is above the normal, then the condenser should be carefully examined. Finally the copper contacts of all interrupters need replacing from time to time, as they become burnt through from long usage, this leading to bad and intermittent working.

Improved Mackenzie Davidson Interrupter.—This is a useful form of mercury interrupter when an outfit of moderate capacity is all that is required, and when accumulators are used as the source of supply.

It consists of a metal pot containing a supply of mercury into which a contact set at an angle dips. The contact consists of a copper blade, which, revolving on a shaft, alternately, by dipping in the mercury, makes and breaks the current at each revolution. This interrupter has been improved recently by Sir James Mackenzie Davidson by the addition of an ingenious mechanism, a rectifier, which picks up the current at make and break, passing both through the tube. In this way the inverse current is utilised to increase the output of the tube, offering possibilities of obtaining much larger currents in the tube circuit, and therefore greatly increasing the usefulness of the interrupter. This contact is mounted on the end of the shaft of a motor whose speed can be varied in order to vary the number of interruptions. This interrupter requires rather more mercury than most of the other types.

Electrolytic Interrupter.—This type was introduced by Professor Wehnelt. The principle of construction is simple. A platinum wire and a large lead electrode are immersed in diluted sulphuric acid in the proportion of acid 1 oz. to water 5 oz. The specific gravity of the mixture should be 1·2. It may be tested from time to time by using a hydrometer. Variations in the specific gravity may explain the defective working of the interrupter.

Fig. 18.—Three-point electrolytic interrupter. (Siemens.)

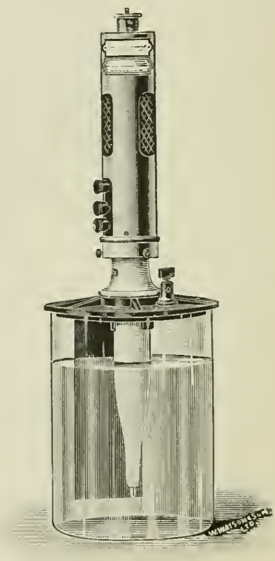


Fig. 19.—Single-point electrolytic interrupter. (Watson.) The upper part of the interrupter has attached to it a solenoid which is connected electrically to the switch-table, allowing of the control of the depth of point in the fluid.

This interrupter is without doubt a good one, far exceeding the best mercury interrupters, not only in regard to output and capacity for regulation, but also in simplicity of construction and use, as well as in safety of working. Wehnelt interrupters can be used wherever continuous current is supplied direct, *i.e.* from supply mains, accumulators (at least about 65 volts), or a motor generator, or where single-phase or three-phase current is converted into continuous current by means of rotary converters or electrolytic valves. As all metals, with the exception of platinum, when used for the active electrode, even if the polarity is correct, are rapidly consumed, platinum is always used with these interrupters as the active electrode, because it disintegrates very slowly and therefore gives the best results. These interrupters are manufactured with 1, 2, 3, 4, or 6 separate electrodes, *i.e.* they are used as single, double, triple, quadruple, or sextuple interrupters. When employing a multiple interrupter one is not obliged to regulate at the interrupter itself, and can therefore set it up outside the X-ray room, so that its noise causes no disturbance. The interruptions are very rapid, as high as 1500 or 2000 per second when a small anode point is used. With large currents the frequency is not so great.

The frequency is increased:

(1) By diminishing the size of the anode point.

(2) By raising the temperature of the acid (this happens when the interrupter is used for prolonged runs; for prolonged use it is necessary to cool the acid).

(3) By diminishing the self-induction in the circuit.

The advantages of the Wehnelt interrupter are summarised briefly as follows:

Fig. 20.—Trolley control table, showing the regulating parts.

(1) Simplicity of construction.

(2) Convenient handling of the X-ray outfit. The Wehnelt interrupter requires no attention.

(3) Largest capacity, as it interrupts very rapidly the largest amount of energy and, therefore, the most intense X-rays are obtained.

(4) Long life to the tubes even when used with heavy currents.

(5) In comparison with all mechanical interrupters, great reliability. This is due to its simplicity of construction and method of working, the

absence of moving parts, and the consequent simplicity of connections of the whole outfit.

In the case of X-ray outfits for rapid exposures three or more electrodes are arranged in parallel by means of a switch, and the electrodes are so adjusted that each interrupts an equal proportion of the total current.

In conjunction with a time-relay switch these interrupters can be used to obtain exposures of from $\frac{1}{10}$ to 6 seconds in connection with an automatic cut-out switch. With the most powerful induction coil outfit, such as the single-impulse apparatus constructed for use with the electrolytic interrupter, a time-relay should always be included, along with a triple electrolytic break, for then we have a large range of exposures at our command.

Method of Action of an Electrolytic Interrupter.—When a current of at least 50 volts and 5 amperes is passing through the interrupter in such a manner that the platinum is the anode, the density of the current is so great near the small anode that it becomes very hot and steam is formed. In addition, electrolysis causes hydrogen and oxygen to appear, and these gases form an insulating mantle round the anode which interrupts the current. If there is a sufficient amount of self-induction in the circuit, a spark appears at the breaking point, namely the anode, ignites the gases, and the explosion gives the acid access to the platinum, thus closing the current again. This process takes place with extraordinary rapidity and regularity.

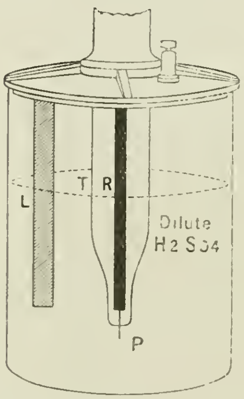


FIG. 21.—Diagram to illustrate the construction of an electrolytic interrupter.
L. Negative or lead electrode.
T. Porcelain sleeve.
R. Lead rod } positive
P. Platinum point } electrode.

The intensity of the discharges and the frequency of the interruptions can be varied in the widest limits by varying the electromotive force used in the primary circuit, the surface of the platinum anode, and the amount of self-induction.

The *disadvantage* of the electrolytic interrupter is the great care that has to be exercised in its use. Unless a considerable latitude is allowed for, the X-ray tube is more likely to be damaged, the anti-cathode being quickly pierced if too powerful currents are used for long periods. When, however, the electrolytic interrupter is provided with three or more points and a suitable switch on the general or main switchboard, all degrees of exposure can be successfully used. Even for therapeutic work this interrupter when properly used is undoubtedly one of the best forms of interrupter.

With a time-relay switch most powerful currents may be used if only for a fraction of a second.

Carelessness in leaving the thicker points in the circuit and then using it for prolonged screening will almost invariably ruin a tube.

A single-point electrolytic interrupter can be controlled from a distant point by means of a solenoid. In this way it is possible to vary the depth of the platinum point in the acid solution and so vary the intensity of the current passing through the interrupter. This is a most useful addition to the electrolytic interrupter.

Interrupters for Alternating Currents.—These are numerous, mechanical and chemical, and enable us to use the alternating current without rectification.

Good though some of these are, none is so efficient as an interrupter on a continuous current circuit, and the maximum intensity which can be reached even with the best alternating current interrupter is much less than that obtainable with a continuous current.

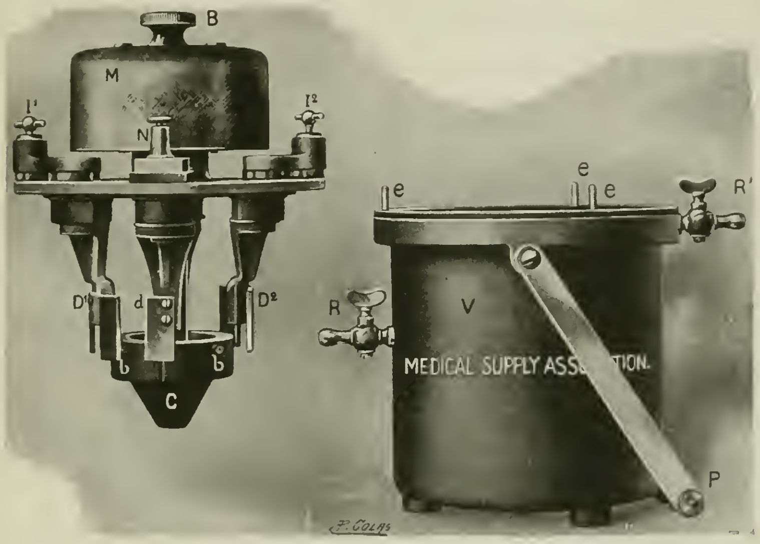


Fig. 22.—Gaiffe interrupter.

V, Vessel. M, Vulcanite cap. R, Inlet tap. *b*, *b*, Orifices.
e, *e*, Screws. B, Impulse. R[1], Outlet tap. *d*, *d*, D[1], D[2], Teeth.
I[1], I[2], N, Terminals. P, Handle. C, Cone.

When the alternating supply has a higher periodicity than sixty it is better to rectify the current by installing a motor transformer or to use an alternating high-tension rectifier.

With a periodicity of less than sixty, and not less than forty, one of the best interrupters to use is that made by Gaiffe of Paris. This interrupter and a Gaiffe Rochefort transformer or coil may be used for therapeutic work by utilising fewer of the contacts in the interrupter, but when required for radiography the intense current is used. This is done by a mechanical contrivance which throws all the teeth in the interrupter into action. Quite rapid exposures may be obtained with this apparatus, especially if intensifying screens are used. Other types of mercury jet interrupters may give equally good results. They are now constructed to carry up to 50 amperes, and are provided with two motors, one being used to ensure perfect synchronism. They give practically the same output as those which are used on a continuous current circuit.

The mercury jet is obtained, as in some of the previous interrupters, by the rotation of a cone with its lower end in mercury, and by centrifugal force the mercury is jetted out against the stationary contacts. The motor part differs from the continuous current interrupter. The break is started with a smart twist of the milled head on top and the needle of the milliammeter watched until this is steady, this indicating that the interrupter is in synchronism with the supply. Some operators can judge of this by sound. At first there is a grating sound, and this becomes smooth when synchronism is attained.

Methods of dealing with Inverse Current

The apparatus already described consists of the induction coil working with either a mercury or electrolytic interrupter. The chief objection to

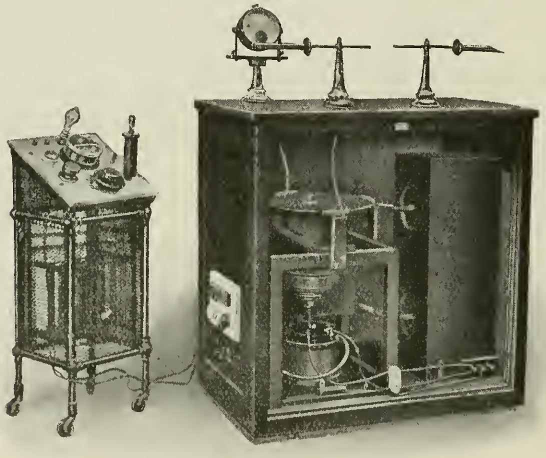


FIG. 23.—Rectipulse outfit with front removed to show arrangement of parts. (Watson & Sons.)

this combination is the presence of reverse current in the circuit, necessitating the use of valve tubes for its suppression. Leslie Miller succeeded in checking the reverse current by the introduction of a mica disc valve. Morton has also introduced a rectifier which gets rid of the reverse current. Mackenzie Davidson has suggested an ingenious apparatus for the utilisation of the reverse.

Gunstone in the "Rectipulse" apparatus deals with the reverse current in a different manner; by a mechanical device attached to the interrupter he diverts the current which appears at the "make" so that it moves in the same direction as that of the current at "break," and therefore supplements it instead of antagonising it. This result is produced by the primary being arranged in such a way that the magnetisation of the iron core is reversed *in sign* at each successive impulse. It is in this respect that

Gunstone's arrangement differs from that of Mackenzie Davidson. The apparatus closely resembles the operation of a transformer, but has the advantage that the impulses are of the same nature as those given by the mercury interrupter under ordinary conditions.

Description of the Apparatus.—For convenience, the apparatus is usually mounted in a cabinet, which accommodates the induction coil, the interrupter and rectifier with speed regulator. On the top of the cabinet is mounted a spark-gap and milliamperemeter. The apparatus is controlled by means of a switch-table, which contains the regulating resistance for the current passing to coil, amperemeter, and switches. In other words, the apparatus is built in units which can easily be assembled and quickly connected together and regulated by means of a central control, which can be brought up to the upright screening apparatus, or to the side of the radiographic table.

High-Tension Step-up Transformer

This type of apparatus is merely an oil-immersed step-up transformer which is supplied with alternating current from an alternator. A rotating pole-changing switch rectifies the high potential current from the secondary of the transformer.

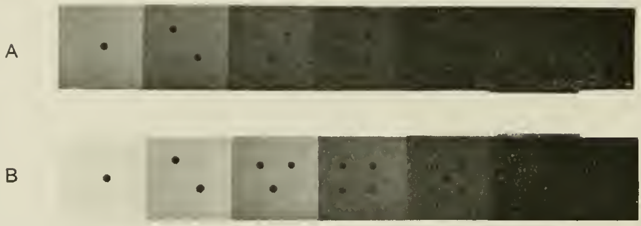
To secure synchronism the commutator is mounted upon the same shaft as the alternator. The current is not uniform but pulsating. The output from such a machine can readily be varied from 1 to 100 milliamperes.

It is stated that for general X-ray work the coil is more efficient than the high-tension transformer, requiring less current in the secondary to produce the same result. This is undoubtedly true. The explanation given is that the sinusoidal current curve of the high-tension transformer is not quite so efficient as the long steep peaks obtained from an induction coil (see Figs. 24 and 25), and that they are more destructive to the X-ray tube. The latter may be true of the tubes in use up to a few years ago, but it does not apply to the Tungsten target tubes now used, and certainly not to the Coolidge tube, which works equally well with either type of apparatus for the exposure necessary in radiographic work, or for screening when care is taken not to use a current in the secondary exceeding 3 to 4 milliamperes.

X-rays of sufficient hardness to penetrate the glass of the tube are generated only when the Electro Motive Force of the discharge has a definite high value. With an induction coil this high EMF exists practically during the time of the discharge; with the interrupterless alternating transformer the EMF has a sufficiently high value only during the short time the wave is near its height, the beginning and the end of the wave being of no great value for the production of X-rays of any degree of penetration, though they are still capable of influencing the milliamperemeter; they also produce heat which acts on the tube.

Experiments carried out by W. G. Schall with the two types of apparatus, using the same number of milliamperes and the same length of exposure, appear to show that the coil gives under the same conditions a greater value in penetrating rays.

The accompanying figure illustrates this point:



A and B are positives from negatives obtained of an aluminium ladder taken with the same tube and the same number of milliampere-seconds.

A was taken with a spark coil with 6 milliamperes and 12 seconds = 72 milliampere-seconds.

B was taken with an alternating transformer 6 milliamperes and 12 seconds.

The result in A is much better than in B.

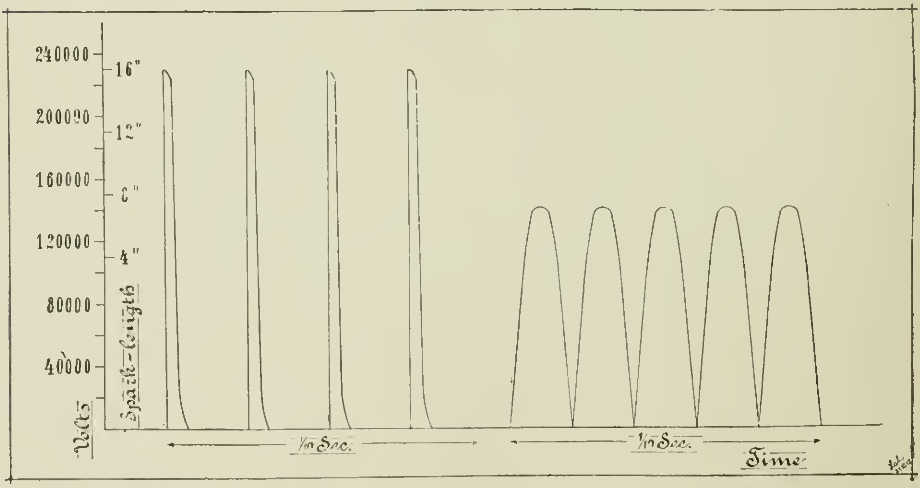


FIG. 24.—Diagram of the discharge from a spark coil.

FIG. 25.—Diagram of the discharge from an alternating current transformer. (Schall.)

It is also stated that in order to get an equally good picture with an alternating transformer it was necessary to give an exposure of a little over 300 milliampere-seconds, that is, more than 3 times the exposure given in the experiment A, or 300 to 72 milliampere-seconds.

The plate facing this page shows the results of experiments carried out with a view to corroborating the above. They were conducted under the same conditions as nearly as possible. The same measuring instruments were used, and also the same tube. The transformer was a Victor machine, the coil a 16-inch one.

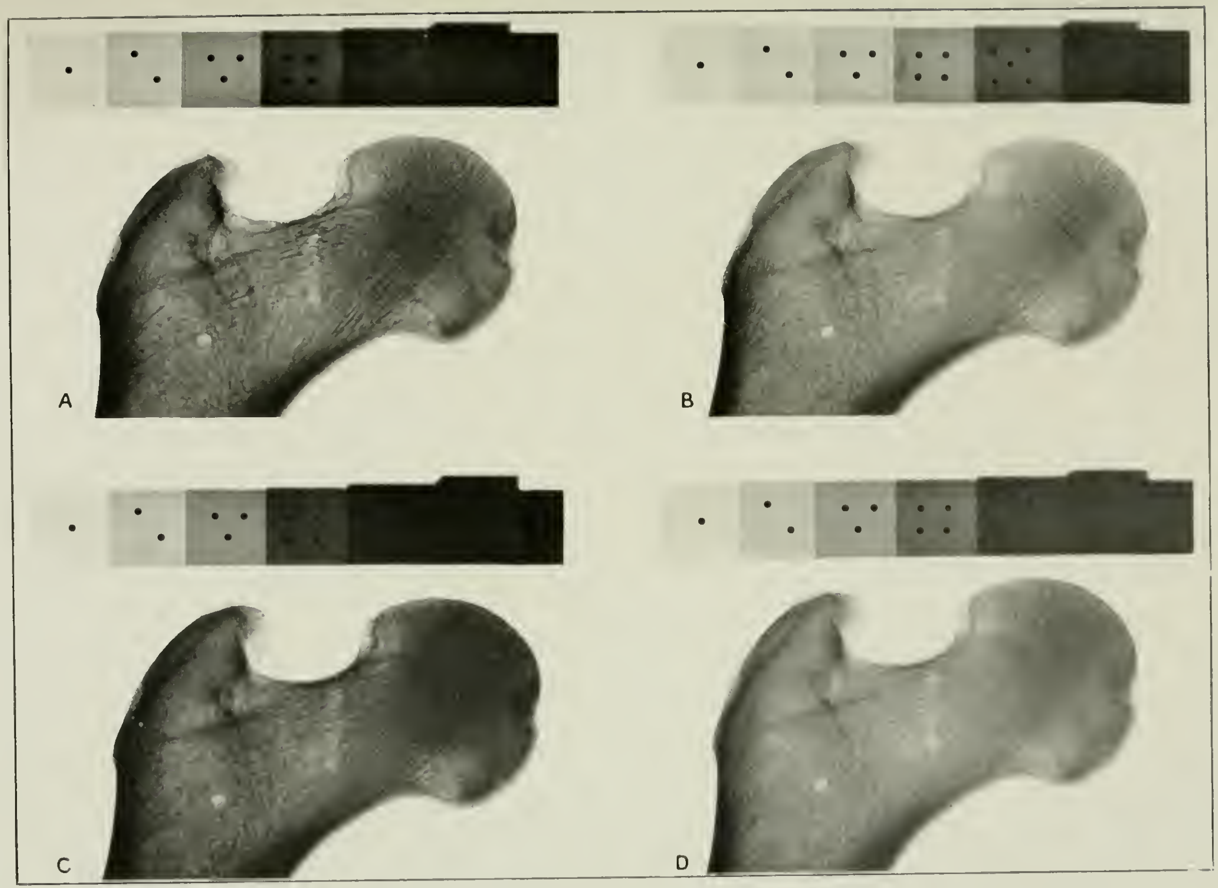


PLATE II.—Result of Experiments with an Induction Coil and with a High-Tension Transformer.

Dry head of femur, with penetrometer scales. Measurements taken with the same instruments and four exposures made on one plate in order to insure equal development.

Particulars of experiments					
Coil	A.	2·8 inch spark,	5 m.amp.,	10 secs.
	B.	4·75 ,,	$2\frac{1}{2}$,,	8 ,,
Transformer	C.	3·0 ,,	3·5 ,,	15 ,,
	D.	4·75 ,,	3 ,,	6 ,,

In this set of experiments the difference is in favour of the induction coil, but there is not nearly so large a variation as in the experiments shown by Schall. The matter is still worthy of an extended series of experiments.

Description of Apparatus for Time and Rapid Radiography

The following descriptions are given as types of the class of apparatus most likely to be useful when very rapid work has to be done. They are

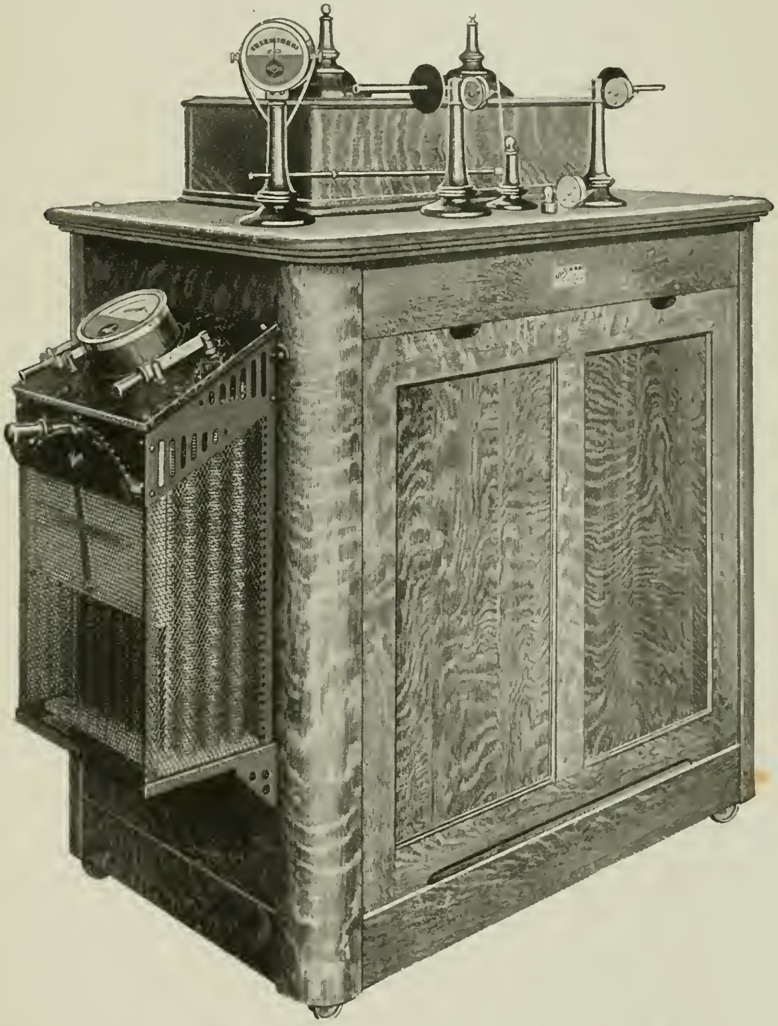


Fig. 26.—Victor interrupterless transformer. (Watson & Sons.)

by no means the only instruments capable of doing this type of work. Individuals vary in their choice, and the many variations seen in different clinics are all useful; any one might be the ideal.

The Victor Transformer is admirably adapted for radiography, fluoroscopy, and therapy, auxiliary interrupters or other attachments not being required.

It has a single lever control, thus eliminating the use of all superfluous switching mechanism.

This apparatus has proved economical in the use of tubes with ordinary care and handling.

It is simple in construction and is very smooth in running.

Great improvements have been made in the high-potential rectifying switch and the type of motor employed, and it is practically impossible to throw the apparatus out of synchronism. In the radiography of the moving parts of the body, such as the viscera, all exposures are made instantaneously.

All switches and meters are in close proximity to one another, the control system being made an integral part of the apparatus; or they can be mounted separately to suit the requirements of the operator.

High-Tension Transformer

The Wappler Interrupterless Machine.—The essential features of an X-ray machine are as follows: (1) An abundance of power; (2) efficient transformation; (3) varied limits of electromotive forces (in this type of machine five steps). These transformers possess great advantages by virtue of their various steps of transformation—the only means of methodically working technique and securing certain results in radiographic work. The lowest secondary voltage is 25,000, the highest 100,000, with three steps between. The high-voltage, low-amperage current is suitable for treatment and fluoroscopic work.

Insulation.—As the result of experience it has been proved that high-tension currents cause the generation of nitrous oxide, which, combining with moisture in the air, forms conductive and corrosive elements on and in the materials. The corrosive compounds generated settle on the parts of the apparatus where discharges of current take place, forming paths over which the current leaks away from the discharge terminals. In order to insulate the high-voltage current properly, so that the constant stress will not eventually destroy the efficiency, such materials must be chosen as are non-combustible and will not absorb moisture. This may be ensured by using heavy plate-glass and a micanite rectifying disc. Both are non-combustible and will not absorb moisture. All discharge terminals and brushes are mounted on this plate-glass. All other materials commonly used to-day—such as rubber, fibre, marble, wood, etc.—readily absorb moisture and become carbonised.

Transformer.—The closed magnetic circuit transformer is employed for the production of the high voltage on account of its efficiency, and also because of the ease with which the secondary voltage may be varied by the simple variation of the ratio of windings. A third reason is that very high milliamperages may be obtained for fast work without endangering the transformer.

The transformer is dry-insulated by a wax composition which has been used with great success for many years. Long experience has proved that this transformer is far superior to the oil-insulated one, being cleaner, more easily portable, and much less liable to break down. It is particularly commendable because of its high capacity, being perfectly insulated to withstand the highest stress when using very high vacuum discharge tubes.

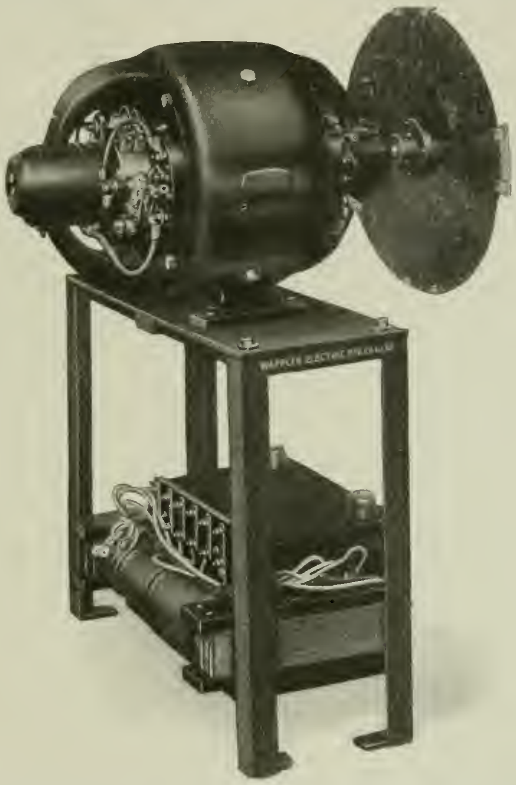


FIG. 27.—Direct current rotary and rectifying disc, mounted on iron platform and showing a dry insulated closed magnetic circuit transformer with the variable potential taps.

Direct Current.—A rotary converter on the direct current has received a great deal of attention in the past. For X-ray purposes the ordinary stock type of rotary has been found wanting in various points, and a rotary that is of the true and correct type necessary for this work is now used.

Alternating Current.—On the alternating current, the problem has been to secure a good self-starting synchronous motor to drive the rectifying disc mechanism. A small, single synchronous motor is a decided advance in this respect. It is silent running, brushless, and commutatorless. It starts instantly, and requires but a single switch to put it into circuit.

To hold the motor rigidly in place and in constant alignment a good base and foundation are necessary. To ensure this an iron platform is used, mounted on iron supports and thoroughly braced ; no part of the machine except the cabinet itself is of wood — a vital point to bear in mind.

Switchboard.—The control switchboard is made of highly polished slate. Mounted upon it are all control switches, each one heavy enough

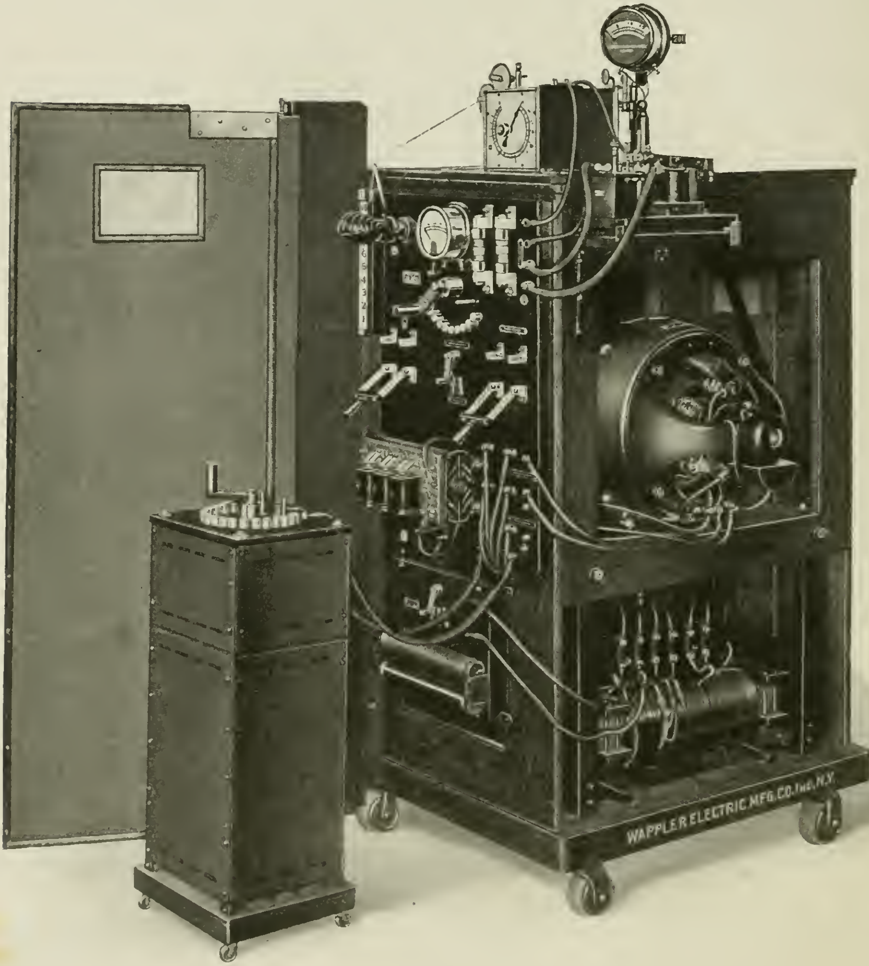


FIG. 28.—Direct current interrupterless transformer, showing rear of machine and switchboard with large capacity rheostat, serial timer with mercury dip, X-ray meter and lead-lined protection screen attached.

An examination of this piece of apparatus shows how complicated the mechanical construction of an X-ray machine has become, and clearly demonstrates the need of a considerable degree of technical knowledge on the part of the radiologist.

to carry the highest loads, fuse-connecting blocks, and high-tension voltmeter. In addition, a large-voltage selector switch is conveniently mounted, so that a change in voltage may be effected immediately. The switchboard is readily detached from the other apparatus and may be placed at any desired position. On the alternating current switchboard a polarity indicator is mounted. This adjunct indicates the polarity of the discharge current and enables the operator to predetermine the polarity. The rheostat consists of a large heavy unit, separate from the switchboard, with control lever in a convenient position.

On the top of the cabinet are a tube vacuum-reducing arrangement, discharge terminals, and a milliamperemeter, located so as to be seen from any position. The meter is equipped with a shunting mechanism by which the change of scale-reading may be effected by merely pulling a string. In addition to this, a variable spark-gap is mounted to the discharge terminals in such a way that through an indicator placed on the switchboard the inches of discharge or " back up " of the tube may be noted.

The closed-core transformer is arranged also for treatment and fluoroscopic work. This is done by means of an extra-resistance control of a high-voltage discharge and low-amperage current flow, so that very fine regulation may be obtained without overheating the X-ray tube.

The Motor Set. Direct Current Apparatus.—It must be understood that the principle of the above machine (the combination of a transformer, etc.) is applicable to an alternating current supply only, *but if direct current is the source of supply, then a rotary converter is used to produce an alternating current from the direct current.* **The motor set** consists of a rotary converter on the direct-lighting circuit, either 110 volts or 220 volts. The rotary converter changes the direct current into an alternating. The low-potential alternating current collected from the converter side is passed through the primary of the transformer, which transforms its potential to about 100,000 volts, at a primary current of from 1 to 3 amperes, depending upon the supply voltage used. The high-potential alternating current is then conducted from the transformer to a rotary pole-changer, mounted on the shaft of the converter.

The rotary pole-changer consists of a round micanite disc. To the periphery of this disc are fastened copper strips opposite each other, and occupying a little more than a quarter of the circumference. Parallel to this disc is a glass plate, on which are mounted four contact plates and brushes equidistantly apart. They are arranged to commutate the current and rectify the high-tension alternating current to a high-tension unidirectional current. The alternating current enters, so to speak, at two opposite contacts, and the rectified current is taken from the two remaining contacts and conducted to the outlet terminals.

Alternating Current Apparatus.—The outside mounting and finish of this apparatus is similar in every respect to the direct-current machine. *The transformer is connected directly with the incoming street mains through the necessary rheostats and switches.* A self-starting motor set, connected directly with the supply mains and operating with absolute synchronism with the line circuit, governs the rectifying device. The small size and noiseless operation of this set is a special feature of the apparatus.

When using the high-frequency currents in treatment work, the synchronous motor set is not operated, current being taken direct from the transformer, removing any possible wear or heating from long-extended use.

Rectifying Device.—Fig. 29 shows the elementary principle of the closed circuit-transformer. A is the primary coil, B the secondary, or high-tension side. This secondary is designed to give a sufficient voltage to jump across an 8- or 10-inch gap.

The character of an alternating current has a wave form, as shown in Fig. 30, the shaded areas C-D giving a complete cycle. The wave form of the secondary discharge is also the same. However, it cannot be used

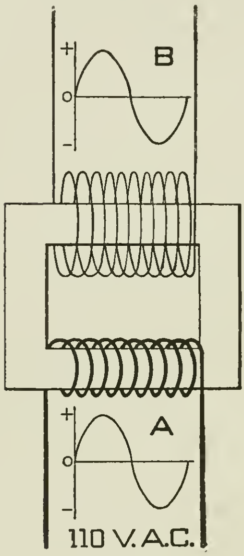


Fig. 29.

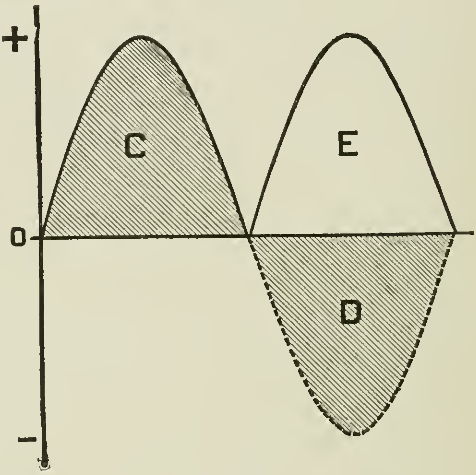


Fig. 30.

for radiographic work, as the wave must be of a pulsating nature, totally on the one side of the zero potential line, to make the current unidirectional. To obtain this characteristic a mechanical rectifying device is needed. This is seen in Fig. 30, C, the wave. On its downward slope it intersects with the zero line. At this point it is necessary to reverse the electrical conductive paths so as to take the next wave or alternation and transpose it to position E, making it unidirectional.

Figs. 31 and 32 give a diagrammatic idea of the rectifying device. F is the mica disc, G and H are two copper commutator strips fastened to the periphery of the disc opposite each other and occupying a little more space than a quadrant. J and K are high-tension alternating current brushes. L and M are the brushes which receive the rectified current. For one complete cycle, or two alternations, the disc makes half a revolution. Fig. 31, wave form C, shows the first alternation during this period; the disc has made a quarter of a revolution and attained the position shown. Fig. 31, Nos. 1 and 2, are the alternating high-tension current leads to J and K.

The wave C shown between Nos. 1 and 2 is the character of alternation. Assume No. 1 is of positive (+) polarity in that instant. The direction of the flow is then shown by the arrows. The wave form after rectification is shown between conductors Nos. 3 and 4. In Fig. 32, D, is shown the next alternation and reversal. The disc has now changed its position from Fig. 31 to Fig. 32. Conduit No. 2 is now positive and the current flows as shown by the arrows. It can be seen that the polarity of the discharge has still been maintained, showing that all the positive (+) impulses are conducted along No. 3 and the negative (−) impulses along No. 4; thus giving absolute unidirectional current.

The current is at all times under perfect control of the operator. The primary winding of the transformer has five sections, each section allowing a

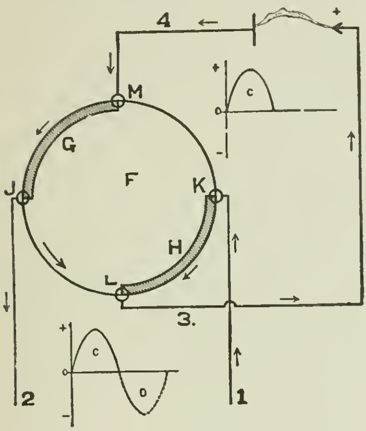


Fig. 31.

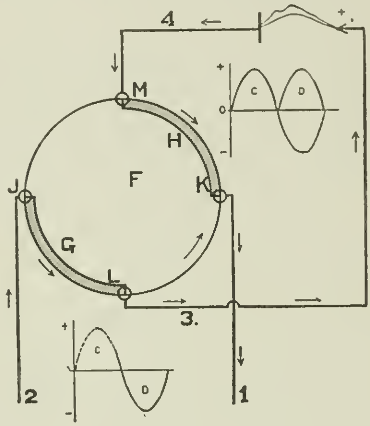


Fig. 32.

minimum and maximum potential, which, worked in conjunction with the primary rheostat, allows gradation of current. The switchboard is hung on the right side of the cabinet, and directly below it is a large-capacity rheostat, which in turn is connected to the switchboard. On the switchboard is arranged a switch for selecting the various windings so as to control the voltage in steps of 25, 45, 65, 80, 100 thousand volts. In X-ray treatment or fluoroscopic work this feature is essential, as a high-voltage discharge and a low-amperage flow are necessary so as to insure high penetrability and constancy of vacuum in the X-ray tube. In addition, a high-tension voltmeter indicates the drop in voltage or "back up" of the X-ray tube in use; thereby giving a gauge as to its penetration and a basis for calculating dosage and energy delivered in X-ray treatment work.

By this method of rectifying, there is absolutely *no inverse* current. This is of vital importance in securing successful radiographic results and insures longer life to X-ray tubes. Owing to the enormously increased output of energy from this transformer, more X-rays can be generated and tubes of higher penetration can be excited than heretofore; thus shortening time of exposure, giving better detail, and penetrating thicker parts of the body than formerly.

These machines are furnished for the 110-volt and 220-volt direct current or the 110-volt or 220-volt, 40, 50, or 60 cycle alternating current. In ordering this type of apparatus it is necessary to give definite information as to exact voltage, and whether the current supply is continuous or alternating. When an alternating current is used it should be stated, also the number of cycles and the phase.

An improvement of this type is announced. The difference between it and the usual model lies in the control. A high-tension transformer of the shell type is used, which has a core of the highest grade transformer iron. There are no taps from the primary. Both primary and secondary are insulated in special wax compound. In the primary circuit an auto-transformer is used, and with this the voltage of the primary of the high-tension transformer is varied at will between 140 volts and 300 volts in steps of 16 volts. On the switchboard is a sliding switch with eleven contact buttons, six active and five dead. These alternate with each other so that the switch cannot make contact with two active ones at the same time. The active buttons are numbered from one to six, and are connected to taps from the auto-transformer. Each tap represents 16 volts, or a maximum of 80 volts. Beneath the sliding switch is a double-throw switch with which the primary and secondary windings of the auto-transformer can be reversed relative to each other—either can be made primary or secondary. One side is marked " High " and the other " Low." With the sliding switch on the first button 220 volts pass whether the other switch is on " High " or " Low." If on " Low " each successive button of the sliding switch reduces the primary voltage 16 volts, but if on the " High " each button increases it 16 volts. It is thus possible to get :

Button.	"Low."	"High."
1	220	220
2	204	236
3	188	252
4	172	268
5	156	284
6	140	300

This gives a range of voltage as follows :

Button.	Primary Voltage.	Secondary Voltage.
6	140	45,000
5	156	53,000
4	172	61,000
3	188	69,000
2	204	77,000
1	220	85,000
1	220	85,000
2	236	93,000
3	252	101,000
4	268	109,000
5	284	117,000
6	300	125,000

Because an inductive rheostat is not used, increasing the quantity of current passing does not increase the voltage very much, therefore any quantity can be obtained at any desired voltage. This type of machine possesses advantages over other types and should be especially useful when the Coolidge tube is used.

The Snook apparatus was the first interrupterless machine made in a practical form for X-ray work, and was first introduced and made in England in 1907, the credit of this particular design being entirely due to Mr. H. Clyde Snook of Philadelphia.

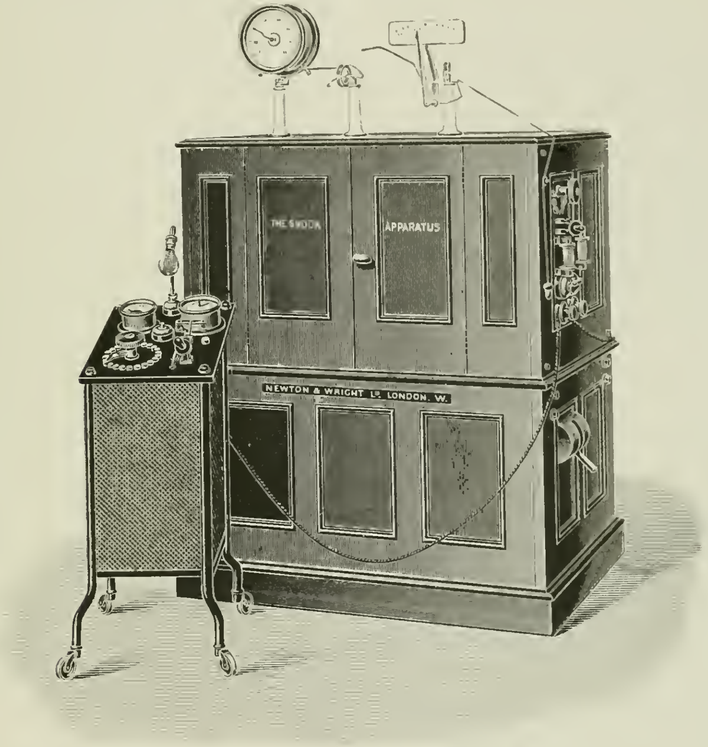


Fig. 33.—Snook apparatus. (Newton & Wright.)

The machine consists essentially of three parts: the motor converter, the high-tension transformer, and the high-tension rectifier or commutator. In the case of the machine designed to run on continuous current, the part first named consists of a motor usually about 4 k.w. in size, which runs from the main at about 1500 revolutions per minute. This machine has a pair of so-called slip rings, from which can be obtained an alternating current.

This alternating current is connected to the primary circuit of the transformer, through a controlling rheostat, and is raised in electrical pressure or voltage to the necessary tension for X-ray work.

This high-tension current is, however, alternating in character whereas for the production of X-rays it is necessary to have a discharge in one direction only, and the latter is obtained by means of the high-tension rectifier.

This consists of a number of ebonite tubes, through which conductors pass, mounted on an axis, and rotated by the motor converter.

In revolving the conductors collect the current from the secondary or high-tension side of the transformer to the spark-gap, to which the X-ray tube is finally connected, and also reverse the direction of the part of the alternating current, which would otherwise pass through the tube in the wrong direction.

The great feature of the machine is that this rectifier is carried on the shaft of the motor which is generating the initial alternating current by virtue of its rotation, and therefore the machine cannot get what is called "out of phase."

The general arrangement of the different parts is shown in the diagram below, and the whole mechanism is entirely enclosed in a cabinet of polished woodwork to deaden the otherwise disagreeable noise of the apparatus when in action.

If an alternating current is available, the motor converter is replaced by a small synchronous motor for rotating the rectifier, *the main current being used in the transformer direct.* In this case the synchronous motor must be very carefully designed and constructed, otherwise it will cause trouble if there is any possibility of its running other than absolutely in step or synchronism with the current.

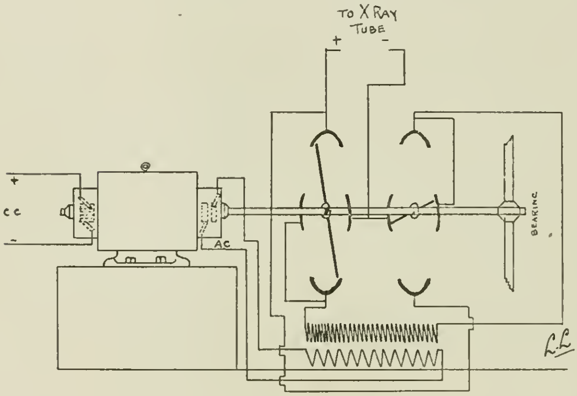


FIG. 34.—Diagram of Snook apparatus. (Newton & Wright.)

The apparatus is much preferred to an induction coil by many workers, owing to the possibility which it affords of using very heavy currents, enabling practically instantaneous radiograms of any part of the body to be taken, and also on account of the ease with which the current can be regulated.

The machine, moreover, produces a perfectly unidirectional current, entirely free from any inverse discharge in the wrong direction, which is a great advantage from the point of view of the life and general working condition of the X-ray tube.

Accessory Apparatus for the making of Time and Instantaneous Exposures.—The short exposures, amounting in all to a few seconds, can be readily given by the use of a stop-switch and the control of the main switch on the distribution board, but when it is necessary to give very short exposures, then recourse must be had to one of the numerous mechanical and electrical timers. These are arranged to give exposures of from $\frac{1}{120}$th of a second to 3 or more seconds according to the particular type selected.

Timing Apparatus.—Fig. 35 shows an excellent device for timing the excitation of the tube. It is simple, accurate and reliable, and with its aid one can obtain a great range of time exposures.

The Teleflasher is constructed in two units. The circuit breaker switch (which opens and closes the primary circuit of the X-ray generator) is housed within a chamber which is filled with oil, the function of the oil being to absorb the arc as the circuit is opened, and at the same time it minimises the wear of the switch contacts and moving parts. The actual work of opening and closing the circuit breaker switch is done by two powerful solenoids, which are in direct mechanical engagement with the switch, these solenoids, however, being independently energised from the 110-volt mains and automatically controlled through the timer as hereafter described.

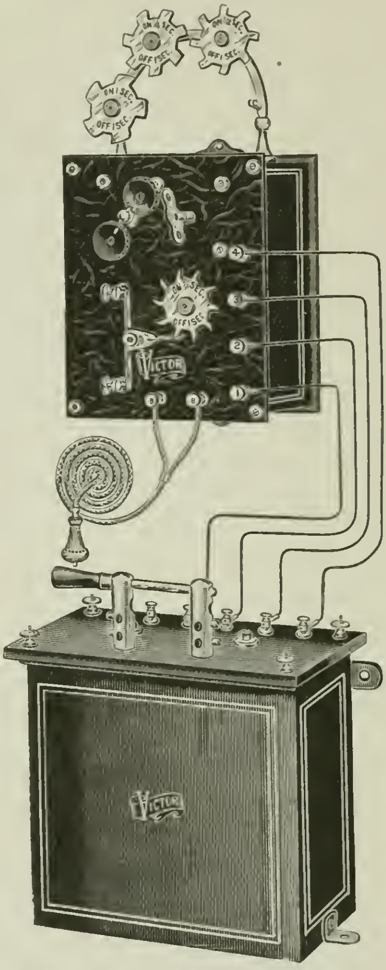


Fig. 35.—The Victor Teleflasher. (Watson & Sons.)

The timer which controls the circuit breaker switch is housed in a separate box or case, which may be placed without relation to the location of the circuit breaker switch box, to which it is connected by means of four wires. The spring motor which operates the timer is provided with a governor, or time regulator, which the operator controls by the simple turning, to the right or the left, of a conveniently placed regulating handle. The actual timing is done by what might be termed timing wheels. A stud projects from the face of the timer, the timing wheels being simply slipped on and off this stud. The time wheels are provided with outwardly extending lugs, or cams, which vary in number and in width in the different wheels. Neither the time wheel nor the operating lever which is engaged by the lugs or cams are in electrical connection with the circuit, this part of the timer being entirely mechanical.

The lugs which project from the time wheel act as cams when they come in contact with the operating lever, and as this lever is raised by the cam, it (the lever) actuates a pair of electrical contacts. When the operating lever on the timer is raised by a cam, the current is caused to flow through one of the switch operating solenoids in the circuit breaker box. This solenoid instantly closes the circuit breaker switch, which remains closed so long as the lever on the timer is passing over one of the cams, with the consequence that the X-ray tube is excited during the exact period required for one of the cams on the timing wheel to pass under the lever. As the cam leaves the operating lever, the current ceases to flow through the closing solenoid in the circuit breaker switch box, and is caused to pass through the opposite solenoid, which instantly opens the breaker switch. It is, therefore, quite apparent that, as above stated, during the time the operating lever is raised by the projecting cam on the time wheel, the current is passing through the tube, and during the time the timing wheel is revolving so as to bring the next cam in engagement with the lever, there is an interval of rest, during which no current is passed through the tube.

We will now assume the spring motor to be so regulated that the time wheel will make one complete revolution in ten seconds. It now becomes a simple mathematical calculation to figure the necessary width of the projecting cams to obtain a closed period for any fraction of ten seconds that may be desired, and, of course, the spaces between the cams will represent rest-interval periods. With the outfit is supplied four timing wheels, and on each of these wheels is stamped the " on " period and the " off " period, which can be obtained by their use. For instance, one of the time wheels is stamped " on " one-tenth second, " off " one second. This means that in one complete revolution of the timing wheel there will be ten exposures of one-tenth of a second each, and nine intervals of rest one second in duration. It becomes quite obvious that if the spring motor is speeded up by means of the time regulator, so that the timing wheel makes two revolutions in ten seconds instead of one, then the " on " periods will be one-twentieth of a second and the " off " periods one-half of a second. The operator having four time wheels at his disposal, calculated for different exposure and interval periods, and, in addition, having this control of the speed of the time wheel, it will be quite easy for him to obtain any combination of " on " and " off " periods that he may desire.

The Repeating Serial Timer.—In this instrument we have a radical improvement in the time clock—a device in which less mechanical moving parts are concerned and by which indefinite duplication of results may be made by the simple act of pulling a string. The dial indicator may be placed on any exposure time from $\frac{1}{60}$th of a second to 10 seconds. It remains exactly at the time set until changed, and the indicated exposure can be duplicated an indefinite number of times.

The novel features in this timing device are in the action and readjustment of the timing mechanism. The predetermined periods are precise, and in many repetitions of the shortest period there are no variations. The contacts for the transformer work in air up to 40 amperes ; for greater current strength a mercury dip break is supplied. Because of the simplicity of this device it is not liable to get out of order.

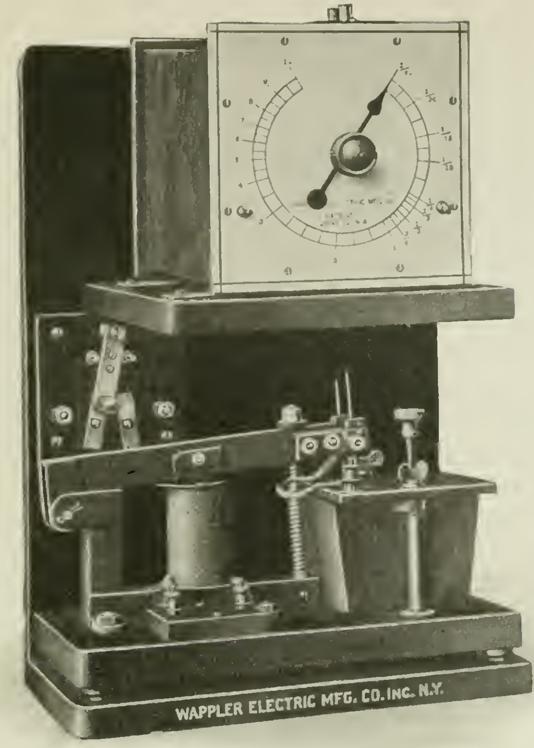


FIG. 36.—The serial timer with mercury dip break for heavy currents.

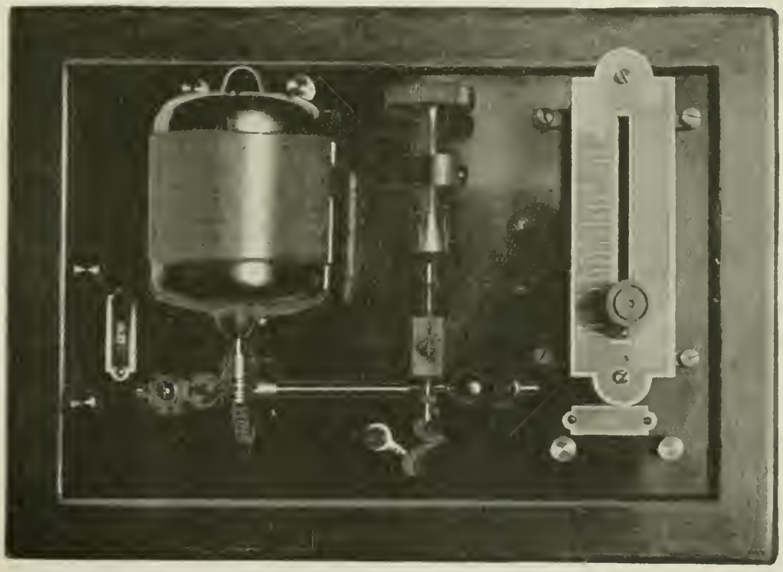


FIG. 37.—Wappler periodic interrupter. (Wappler Electric Co., N.Y.)

The Wappler periodical interrupter consists of a motor, with speed-regulating rheostat and a reciprocating shaft fitted with contacts of large heat-radiating capacity for interrupting the current in the primary. The intervals of interruption and frequency per minute are under perfect control of the operator. This instrument is used in connection with the transformer, or coil, for administering X-ray flashes.

It is provided for either alternating or direct current.

Apparatus for the Production of Single-Impulse Radiographs

The modern high-tension transformer is for general work one of the best forms of apparatus in use, but when very rapid exposures are required it is still necessary to use a single-impulse machine in the form of a large coil or of a transformer which has attached to it a single-impulse switch. The pictures obtained by the single-impulse are in many respects superior to those obtained when a very short exposure of $\frac{1}{10}$ second is used. The shorter exposure of $\frac{1}{100}$th of a second or less gives much sharper detail. This is particularly useful in chest work, especially in cardiac radiography.

The rapid development of the finer methods of examination by means of X-rays has set the designers of electro-medical apparatus a number of new problems. It was necessary to increase the capacity of the X-ray apparatus in order to meet the demands made upon it, particularly when radiographing deep-seated or actively moving organs, when rapid exposures are necessary. It was necessary to evolve new apparatus, not only capable of meeting the requirements of the ordinary X-ray practice, such as therapeutic irradiation, the ordinary X-ray illumination, and the production of time and instantaneous exposures, but also sufficiently powerful to give sharp photographs of organs in motion, such as the stomach and heart.

While in the case of the stomach with its comparatively slow movements an exposure from $\frac{1}{5}$ to $\frac{1}{10}$ second is sufficient to give sharp pictures, in the case of the heart the exposure must be about $\frac{1}{100}$ second in order to produce a sufficiently sharp silhouette of the heart on the photographic plate. The lungs, and especially the glands and vessels at the roots of the lungs, are also well shown in these instantaneous radiographs. The fastest radiographs produced have been taken with a single-impulse break. In these the smallest infiltrations, which would not be easily seen with longer exposures on account of movement due to the action of the heart and lungs in respiration, can easily be distinguished by the observer.

Attempts have frequently been made to solve the problem of taking X-ray photographs with exposures of about $\frac{1}{100}$ second, and the apparatus constructed for this purpose was chiefly based on a single sudden interruption of the primary current of the induction coil, so as to obtain a very powerful inductive current in the secondary, sufficient to produce a brilliant lighting up of the X-ray tube, and the discharge of a heavy current through it.

It is obvious that this single short-current impulse through the X-ray tube must be of great intensity. This implies induction coils of particularly powerful construction differing considerably in electrical and magnetic respects from the customary intense-current induction coils used up to the present for the pseudo-instantaneous exposures. These induction coils are recognised externally by being provided with a heavy and substantial iron core.

In spite of the heavy currents in the primary circuit—currents closely approaching the maximum permissible in the usual supply mains—it was not found possible to secure radiographs of sufficient clearness in all cases, for instance in the abdomen of stout people or distant exposures of the thorax. In such cases recourse had to be had to the customary methods of instantaneous radiography, *i.e.* the use of induction coils working with a mercury or Wehnelt interrupter. For this method of working, however, the single-impulse induction coil, which is very sluggish magnetically, is not very suitable, *i.e.* the times of exposure required when using interrupters were relatively longer than those required with the smaller intense-current induction coils, quite apart from the fact that the short-time exposures ($\frac{1}{10}$ second to $\frac{1}{5}$ second) which might be obtained with the high-voltage rectifier were not nearly approached. An improved apparatus has recently been constructed. This equipment is a combination of the well-known high-tension rectifier with a single-impulse automatic current breaker. It enables radiographs of the thorax to be taken with exposures of about $\frac{1}{100}$ second by the single-impulse method, and permits all other radiographs to be taken by means of the rectifier with exposures ranging from $\frac{1}{10}$ second to 5 or more seconds.

There are other advantages connected with the use of this form of apparatus, in addition to the considerably reduced exposures, which are impossible with the single-impulse induction coil outfit when working with interrupters.

It is of great advantage that the transformer which is used in the customary manner for working with the rectifier is also used for the photographs on the single-impulse method. *As compared with induction coils with open magnetic circuit, the transformer with its closed iron core possesses a much higher efficiency.* This is of particular advantage in connection with the single-impulse method, as the current taken from the power mains may be kept within the prescribed limits, a matter of considerable importance.

In this connection the further advantage may be pointed out that the equipment can be connected directly to 400-volt power circuits ; this voltage is now frequently adopted, but is unsuitable for induction coils, and a reduction in the voltage, which is in most cases not feasible, would be necessary for satisfactory operation.

Using the apparatus as a rectifier the continuous current is converted into alternating current by means of a rotating converter, the alternating current being fed to a high-voltage transformer.

A description of the single-impulse system is as follows :

The alternating current from the transformer is led through the rectifier driven by the rotary converter, the high-tension alternating current being thus converted into high-tension continuous current. This high-voltage continuous current is measured by a milliamperemeter and then led through the X-ray tube.

The current in the tube is adjusted by resistances which are so pro-

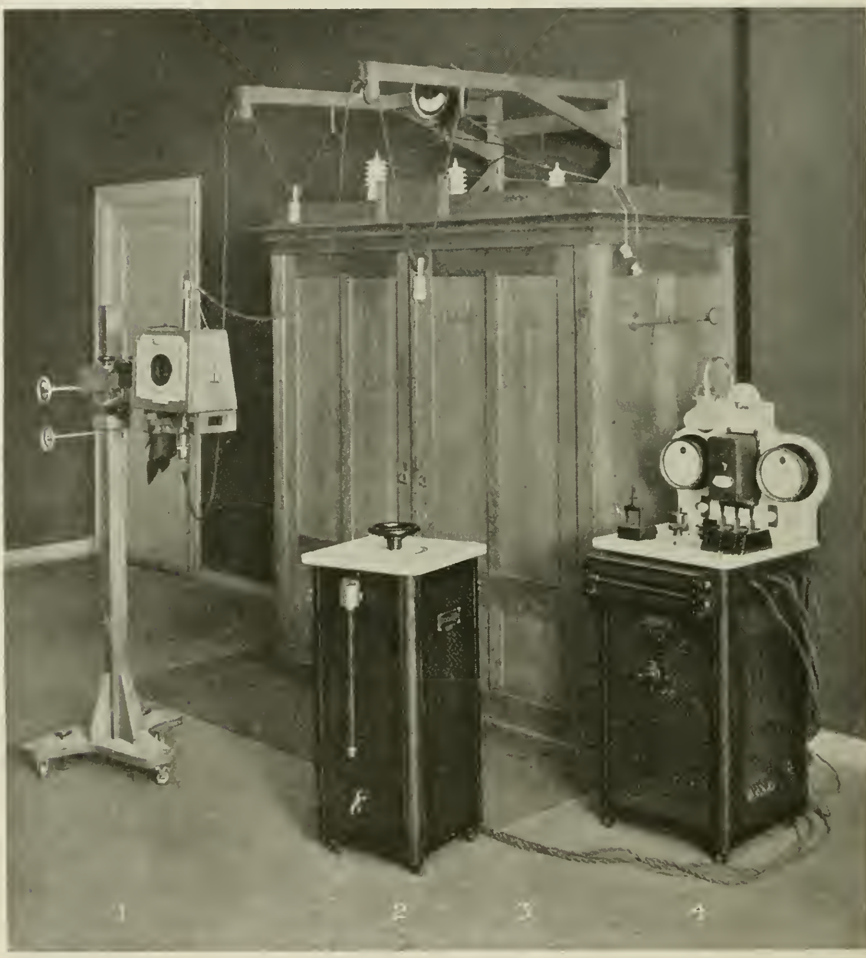


Fig. 38.—Single-impulse outfit (Siemens), showing switch (2), and switch-table with time relay (4), for using outfit as a rotating high-tension rectifier. Cabinet (3) contains single-impulse transformer and rectifier, connected to an X-ray tube (1).

portioned that the current may be adjusted from $\frac{1}{4}$ milliampere to about 80 milliamperes.

When the apparatus is used for the taking of single-impulse radiographs the rotary rectifier is no longer used, but only the high-voltage transformer built into the apparatus. For single-impulse operation the transformer is no longer excited by the alternating current from the converter, but

PLATE III.—Single Impulse Radiograms.

Stomach immediately after ingestion of meal showing divisions of stomach. The remains of a previous meal are seen in the large intestine.

The same case several hours later, showing opaque meal in stomach and small and large intestines. Note the sharpness of detail in both pictures.

obtains its current through the single-impulse switch from the continuous current mains.

The underlying principle of the single-impulse method is briefly as follows: In the methods known hitherto. the current flowing through the primary winding of the induction coil is suddenly interrupted after reaching its maximum intensity, *i.e.* at the moment when the iron core of the induction coil has attained maximum saturation, and the result of the sudden disappearance of the flux is an inductive " kick " in the secondary winding. The force of this inductive " kick " is considerably greater when the single-impulse method is used inasmuch as the flux in the iron core does not merely drop from its maximum to zero but from a positive to a negative maximum. In consequence, the induction in the secondary winding must be particularly strong, and the X-ray tube gives a flash of more than double the intensity that would be obtained with a simple interruption of the current. Measurements have shown that the time of exposure with this method is $\frac{1}{100}$ second. The increase in effect is obtained by reversing the primary current. The whole of the switch operation is carried out by simple manipulation of a hand-wheel at the single-impulse switch-table. After taking a single-impulse photograph, the switch is immediately ready for use again, so that an unlimited number of single-impulse photographs can be taken in succession without any parts requiring to be changed or reset. The intensity of the various impulses can be varied within wide limits by a regulating resistance.

It is obvious that the X-ray tube is subjected to much more severe treatment than in the case of the methods hitherto used. In developing the single-impulse equipment, the problem of making an X-ray tube capable of withstanding these heavy current impulses had to be solved.

The X-ray tubes in general use until quite recently were more or less useless. Even the tubes with thickened platinum anti-cathode cannot stand more than a few flashes with the single-impulse equipment; either the platinum mirror is destroyed or the tube shows signs of being burnt in places. The latter causes blurred radiographs, thus partly negativing the advantages of the single-impulse method with its sharp radiographs. In order to obtain the best results the tube must have a sharp focus point.

It was found that the metal tungsten provided a very suitable material for anti-cathodes as it has a higher melting-point than platinum [1] and is a good conductor of heat, so that tubes in which this metal is employed are capable of withstanding the severe treatment to which they are subjected on the single-impulse method, and it was further found that these tubes can be provided with a sharp focus. Further, as a thick block of tungsten can be used as anti-cathode, such tungsten tubes have an almost unlimited life, whilst platinum tubes are destroyed after several flashes.

It was also observed that in consequence of the advantages mentioned

[1] Tungsten possesses a higher melting-point than platinum, namely 3200° C. against 1750° C., the intensity of radiation is 91 to 100, thermal conductivity 0·35 against 0·17. Tungsten has practically displaced platinum in the manufacture of the anti-cathode of X-ray tubes.

above, the tungsten tubes gave photographs which are richer in contrast and deeper than those obtained with tubes with a platinum cathode.

Essentials for the Production of X-Rays

The chief forms of apparatus and means of utilising the current supply available having been briefly considered, it remains to point out the essentials for the production of X-rays : (*a*) A supply of electric energy ; (*b*) a means of transforming a current of low tension into one of high tension ; (*c*) an interrupter ; (*d*) an X-ray bulb.

The apparatus employed may vary from the simplest to the most highly complicated. Its selection and arrangement will depend upon the operator and the resources at his command. Complicated and expensive apparatus is not absolutely essential to ensure the production of good negatives. The most important point of all is for the operator to make the most of the apparatus at his disposal. When he grasps the underlying principles of the necessary apparatus, and particularly of the technique of radiography, he may venture to add to his outfit those items which are extremely useful but not absolutely necessary. A thorough understanding of the mechanical parts of the installation is of great value to the radiographer, but is not absolutely necessary, because it is generally possible to obtain help in the manipulation of the apparatus. But a thorough knowledge of the X-ray tube is of the utmost importance, because it is always the ruling factor in radiography and therapeutics. In order to produce the best quality of X-rays for a specific purpose in either radiography or therapeutics it is necessary to have accessory apparatus which enables the operator not only to control the X-ray tube but to reproduce at will conditions which are known to lead to the production of good results.

The accessory apparatus is therefore a most important part of the equipment, and must be considered in detail. In the whole organisation of an X-ray outfit the most important point is to have a good X-ray tube under perfect control, then work becomes easy and good results follow.

In view of the importance of this subject the following pages are devoted to a fairly full account of the manufacture of an X-ray tube and the apparatus necessary to enable the operator to exercise an efficient control over it.

X-RAY TUBES AND THEIR ACCESSORIES

The Focus Tube

This being always the ruling factor in radiographic work, a complete knowledge of its construction and method of working is a *sine qua non* in the routine work. Should it not be in proper order the best type of apparatus is quite useless as a producer of good radiographs.

The quality of the focus tube is all-important for success in X-ray work,

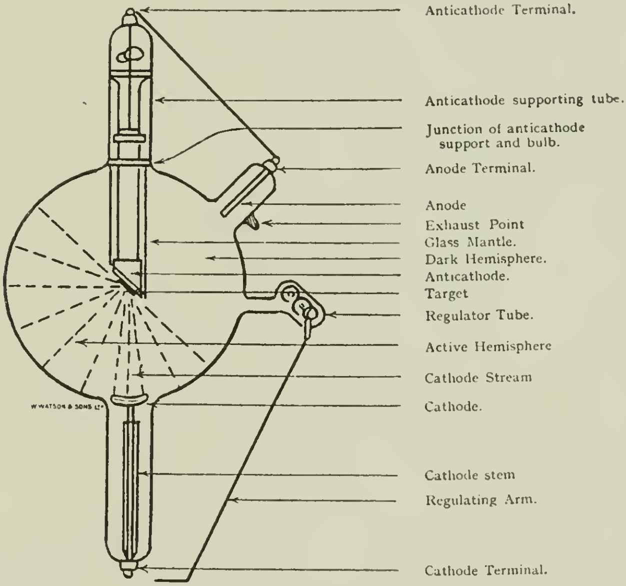


Fig. 39.—Diagram of an X-ray tube with parts named, showing the paths of the cathode stream from the cathode impinging on the anti-cathode ; the active hemisphere shows the paths of most of the X-rays generated. (Watson & Sons.)

for if the tube is unsuitable, in that it is too hard or too soft, it is impossible to get good results.

If, on the other hand, the tube is in good order good results may be obtained with quite ordinary apparatus.

Tubes deteriorate with use, but, carefully handled, they will outlast hundreds of exposures, and show very little sign of damage.

The all-essential point is to know how to use the focus tube, and it is also a great advantage to familiarise one's self with the names of the various parts.

Description of the Manufacture of an X-Ray Tube.—The first process consists of the blowing of a glass sphere of the desired capacity with a " neck," which varies from one to two inches in diameter, according to the size and type of the tube. The thickness of the walls of the bulb is from ·2 to ·6 mm.

The various metal parts, or electrodes, having been carefully cleaned, are introduced through this neck, and are in turn sealed into position by the glass-blower. Connections are made to the outside by fusing into the glass pieces of platinum wire, and as each portion of the tube is finished, it is annealed with extraordinary care. This annealing is one of the most important processes, as an X-ray tube has to withstand the most intense heat.

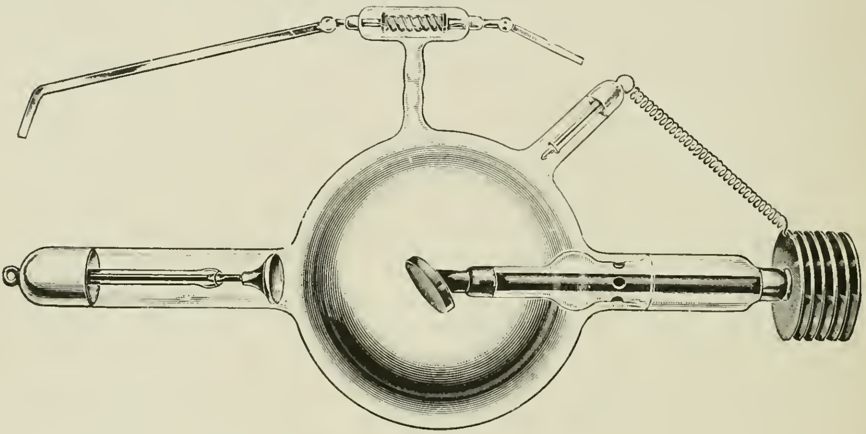


Fig. 40.—Radiator tube constructed for heavy discharges. (A. C. Cossar.)

The electrodes having been placed in position, and the regulators attached, a length of glass tubing is fused on, and the tube is placed on the vacuum pump. The final stages of exhaustion are sometimes very prolonged, varying according to the size of the tube and the nature of the electrodes employed.

A large tube may occupy a considerable time in actual exhaustion. During the process various conditions have to be observed, and it is during pumping that the unavoidable risks of tube-making are greatest, as with the increase of pressure from without, any stress, flaw, or other fault may result in the sudden collapse of the tube.

When exhaustion is complete, the tube is taken from the pump, sealed, tested, and, if found to be in order, is finished off with the necessary terminals.

The Anti-cathode.—The most important part of an X-ray tube is the anti-cathode, since it is here that the heat is generated, and most disturbances take place. It is this part of the tube which is exposed to the intense force of the cathode stream.

The power of resistance to this stream possessed by the anti-cathode of the tube, and the physical effect thereof, is the determining factor in the life of the X-ray tube, and the degree of current it will stand determines largely the amount of work it is capable of performing.

Naturally the anti-cathode varies with each tube, and these are now made for special purposes.

A careful study of the various types of anti-cathode in use will be necessary before the operator can thoroughly understand the best conditions under which the tube will work. The anti-cathodes of some tubes may become incandescent when the tube is running at full current, and a careful watch is necessary when using tubes of this type.

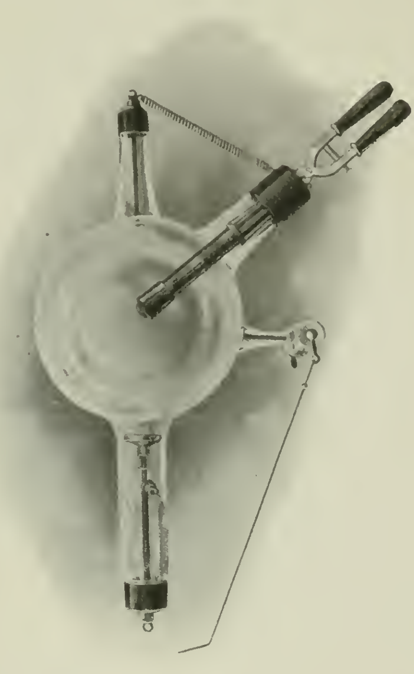


Fig. 41.—Cyclop radiator tube. (C. Andrews.)

The heat generated at the anti-cathode is absorbed and radiated along a solid copper rod which is arranged to facilitate ready removal from the tube. When the copper is heated it may be removed and a second one introduced. By changing these during an exposure, the tube can be kept comparatively cool for long periods, the vacuum of the tube being thereby maintained at a constant degree of hardness.

The cheaper tubes are made with light anti-cathodes. The next class of anti-cathode is that known as the "heavy anode," consisting usually of a copper tube or sleeve of varying thickness and length, and carrying at its extremity a platinum-coated plate similar to that used in the light anode tube. In this case, however, these various metals are welded together into one continuous whole, which is supported on a glass sleeve projecting from the wall of the tube. Naturally this mass of metal has much greater absorption and conductive capacity than the light anode, and will in consequence stand a much greater degree of heating, *i.e.* a higher current. There is also a proportionately large reserve of gas in these armatures, and, unless grossly over-run, such tubes do not become red-hot, and are therefore much more constant in vacuum.

As the weight of metal in the anti-cathode is increased, so (other conditions being equal) the capacity of the tube to withstand a high current is increased also. Occasionally, the metal sleeve of the anti-cathode is greatly extended, and is carried directly to the exterior of the tube, terminating sometimes in a radiating device in order to discharge the heat as expeditiously as possible.

As the difficulties which arise when using heavy currents for X-ray work are almost wholly concerned with such heating, several other methods have been adopted in order to deal with it in an efficient manner. One is the system on which the Cyclop tube is worked. The other is that employed in water-cooled models. These are described at some length.

Water-cooled Tubes.—The general use of X-ray tubes cooled by means of water was, for all practical purposes, commenced by the continental radiographers.

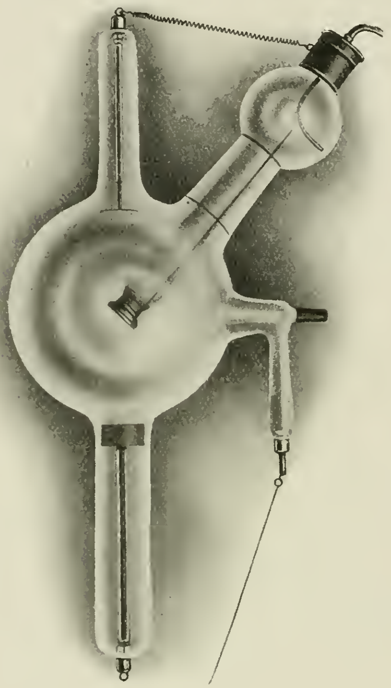


Fig. 42.—Water-cooled tube arranged for overhead work. (Watson & Sons.)

The original water-cooled tube is designed mainly on the lines suggested by Professor Walter. It is arranged in the following manner: In place of the usual heavy metal anti-cathode, a solid platinum vessel is provided, and on to the bottom surface of this is fixed a metal plate which is in turn faced with platinum. The upper or open end of the vessel is sealed on to a glass sieve, which is in turn attached to the wall of the tube, and which is expanded, outside the tube, into a reservoir or water chamber approximately 3 inches diameter. When water is poured in, it passes down the glass sleeve to the platinum vessel, and is thus brought into actual contact with the back of the target. This latter feature is an essential in the construction of a water-cooled tube. Workers are strongly advised not to purchase so-called water-cooled tubes when the water does not reach right down to the back of the target, as such instruments simply omit the vital principle which renders the water-cooled tube so highly efficient.

When the heat is generated by the impact on the target it is immediately imparted to the water, and the temperature of the target can therefore only momentarily exceed that of boiling water—100° C.

Apart from the efficiency of the cooling system, the construction of water-cooled tubes renders them more satisfactory in other respects. In the first place it is possible to make the anti-cathode almost entirely of platinum, which means that there is practically no metal in the tube likely to give rise to violent changes of vacuum. The water-cooled tubes remain therefore at approximately the same degree of hardness for very long periods. The great advantage in this respect cannot be over-estimated, and will appeal both to those who are doing continuous radiographic work, and to those running tubes for long periods for therapeutic purposes. The latter point is of extreme importance for deep therapeutics.

The employment of water as a cooling medium is free from all objection, even from that of extra trouble in manipulation ; for if tubes, when not actually running, are stored in one of the excellent vertical holders now on the market, it is not necessary even to empty the water bulb after use, and the only extra attention entailed is the occasional replacing of the water which may be lost by evaporation.

The principal feature of water-cooled tubes is that they may be kept in continual use for hours, without any danger of over-heating and consequent softening. Further, they will withstand a much larger current than the ordinary tube will take, and in fact the heavier models will for a short time

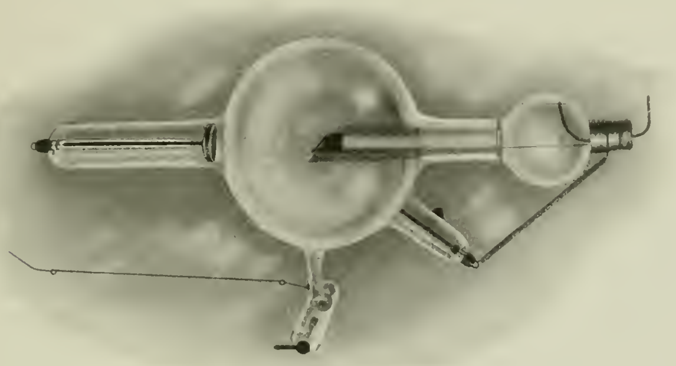


FIG. 43.—Water-cooled tube for overhead or under the couch work, showing mica and carbon regulator. (C. Andrews.)

stand up against the maximum amount of current which can be forced through them.

Selection.—In selecting a water-cooled tube, regard must be paid to the class of work for which it is intended to be used. It must be considered whether the tube is to be used with light or heavy currents, and whether it is to be used only above the couch (either horizontally or vertically), or whether it is desired that it may be used in the horizontal position below the couch.

The tubes for use below the couch are made with the anti-cathode set in the long axis, and are furnished with a curved revolving tube, by means of which the water is prevented from flowing out. The tubes for use in positions other than below the couch have the anti-cathode set at an angle of 45° to the long axis.

Tubes for use with heavier currents are made on an exactly similar system to the lighter models, but differ in that the armatures are strengthened in order to permit of the heavier loads being carried. The most important modification is in the anti-cathode, which is made in the following way: the platinum-faced target is set on a massive block of specially alloyed copper, which is in turn attached to a solid platinum vessel similar to that used for the lighter models. By the interposition of this buffer of alloy the capacity of the tube is enormously increased, and at the same time the amount of extra metal thus introduced is not sufficient to rob the tube of its excellent qualities of constancy and steady working. In fact the whole proportioning and "balance" of these tubes has been worked out with a nice exactness which has been amply justified by the result.

The Use of Water-cooled Tubes.—It must be remembered that this type of tube is designed and constructed to work with a water-jacket, and it must on no account be used without the receptacle having been filled to within about half an inch of the top. In the case of the pattern for use above and below the patient, the opening of the curved tube should be just above the surface of the water, when the instrument is placed horizontally, thus allowing an outlet for steam. If the tube should be inadvertently worked without water, it must be allowed to cool completely down (say, for at least an hour) before water is filled in. If this precaution is not observed, a breakage will in all probability occur.

As already stated, it is not necessary to remove the water after using, and, therefore, there should be little danger of the tube being worked without the cooling medium.

Ordinary tap water should be employed, not distilled nor filtered. Should the tube have been running continuously so that the water is boiling, it is permissible to renew the supply, and this may be done without disturbing the tube, by means of a syphon. By placing a vessel containing water at a lower level than the tube and starting the flow by suction, the water may be run out until only about 3 inches of the water-tube remain filled. The container is then raised to a level above the tube, and water allowed to flow in. If no syphon is obtainable, an alternative method is the following: Pour the boiling water out of the tube into a jug, and add cold water in sufficient quantity to render the whole just distinctly warm to the touch. Then refill the water-chamber with the slightly-warmed water. Obviously, if the boiling water were removed, and cold water filled in, the glass might possibly fracture; but by adopting the above method the supply may be safely renewed. The tube may then be run as before.

In cases where the tubes are used in a horizontal position, care should be taken to raise the water-chamber slightly above the level of the anti-cathode itself, so as to keep the water against the target. This prevents the water flowing away from the anti-cathode, as it might do if the tube were absolutely horizontal, and also allows of the escape of bubbles, etc. The curved tube in the cap may be revolved according to the position of the X-ray tube, so as to permit of the aperture being always uppermost.

If desired, the water can be circulated through the tube by means of the syphon mentioned above. This is very efficacious, but necessary only when very lengthy runs are being undertaken.

There is another type of tube made by several makers which is very efficient and convenient for treatment. This tube has a diameter of about 5 inches (125 mm.). An auxiliary bulb (having a diameter of about $6\frac{1}{2}$ inches) is connected to the tube, thus forming a reserve air-chamber. This construction results in the tube possessing all the advantages inseparable from one having a large cubic capacity; while the fact of the anti-cathode being only $2\frac{1}{2}$ inches from the wall of the tube enables the original Sabouraud distance to be adopted.

Air-cooled Tube.—This is a specially constructed tube, an air pump being employed to supply a forced draught which is sent into the cathode and anti-cathode of the tube. By means of the small electric motor operating the force-pump, air at the temperature of the room is used at considerable pressure. The special modifications of the tube required

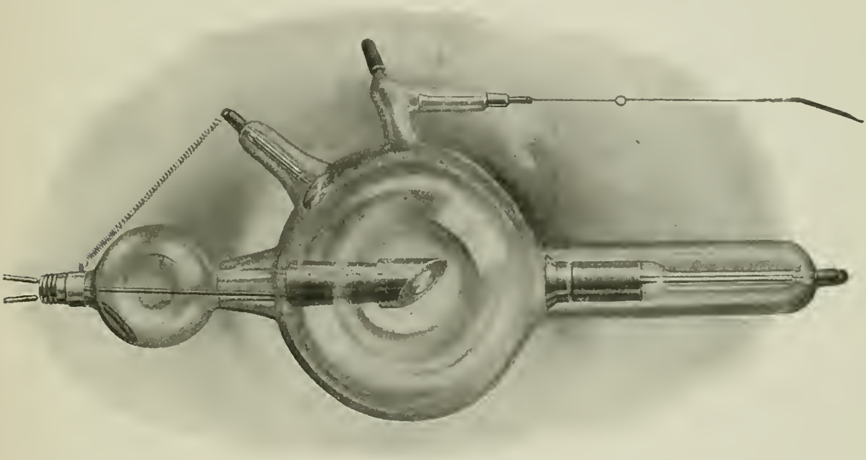


Fig. 44.—Macalaster Wiggin water-cooled tungsten tube. (Newton and Wright.)

are as follows: In place of the ordinary cathode there is employed a very massive hollow armature, with the same diameter as the anti-cathode; into both cathode and anti-cathode are fitted inlet tubes, which bring the cold air into direct contact with the whole inner surface of the armature, and the heated air is expelled through a number of peripheral apertures. The connection between the X-ray tube and the air pump is made by means of strong india-rubber tubes. The cathode is cooled as efficiently as the anti-cathode, this being a very important point. In a tube of this type, currents of at least 5 to 7 milliamperes may be passed continuously without any ill effects.

There has been introduced a further elaboration of this type of tube, *i.e.* a tube working as described above but fitted in addition with an atomiser connected to a vessel containing water. Instead, therefore, of air being pumped on the back of the anti-cathode the water is continuously sprayed on the latter and thus cools the electrodes.

The Pilon Tube is water-cooled, with a metal bulb for water. An additional advantage of this tube is that it may, if desired, be used as an

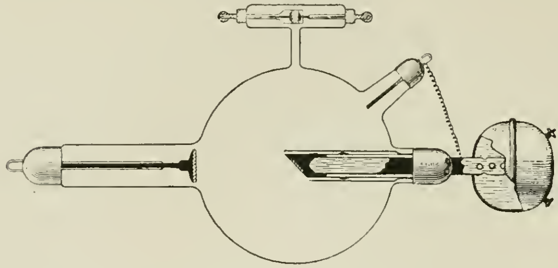


FIG. 45.—Pilon water-cooled tube. (Medical Supply Association.)

air-cooled tube; in that case air is pumped into the metal bulb, which then itself acts as a radiating surface.

Coolidge Tube.—A tube which has been invented by D. D. Coolidge. The tube is devised to be entirely free of gas and has a vacuum 1000

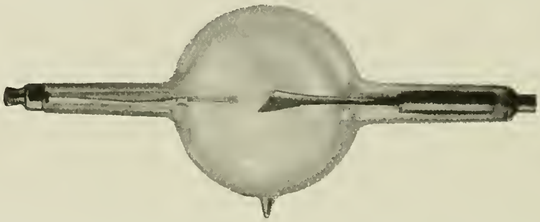


FIG. 46.—Coolidge X-ray tube. (British Thomson Houston Co.)

times greater than the ordinary tube, so that it is impossible to pass a current through it in the ordinary way even with the most powerful apparatus. The anti-cathode is constructed of tungsten, and the cathode, instead of

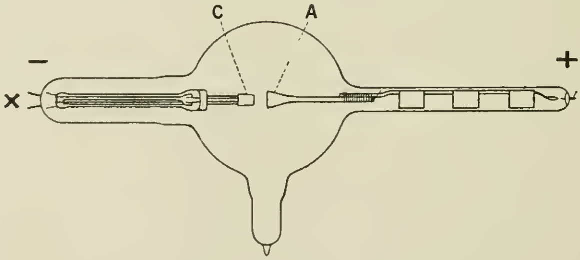


FIG. 47.—Diagram of a Coolidge tube.

A, Anti-cathode.
C, Cathode.
+, Positive terminal.
–, Negative terminal.
X, Connections to heating-circuit.

being an aluminium cup-shaped electrode, consists of a spiral of tungsten wire surrounded by a sleeve of molybdenum to focus the cathode stream. Connected to the cathode spiral is an auxiliary source of current consisting of a small accumulator battery with an ammeter in circuit (it is important that the battery be well insulated from earth), which heats the metal, causing it to give off a stream of negatively-charged electrons which are projected on to the anti-cathode.

The number of freed electrons from the anti-cathode is regulated by the degree of heating of the tungsten spiral, and the speed of the cathode stream, upon which depends the penetrating power of the X-rays, is regulated by increasing or diminishing the potential at the terminals of the tube.

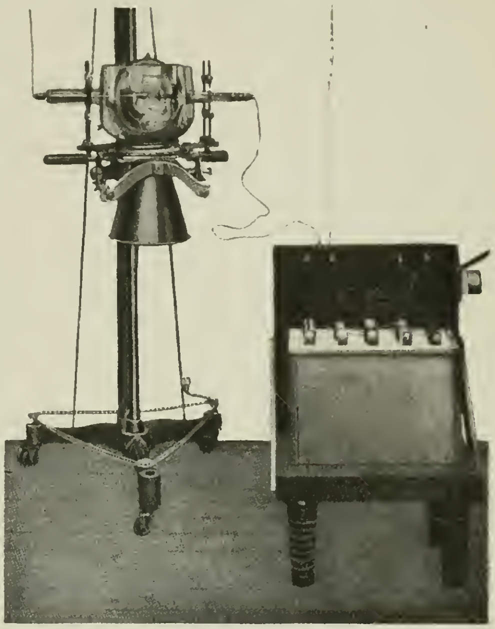


Fig. 48.—Complete Coolidge X-ray equipment in position. (B.T.H.)

It is claimed, therefore, that this tube will give us accuracy of adjustment, stability of hardness, possibility of exact duplication of results, unlimited life, great range of flexibility, absence of inverse radiation, and extremely large output. The chief features seem to be that one can at will have any degree of hardness, and any quantity of rays, and these two factors constant for indefinite periods, and it is also possible to repeat the same conditions at any time. The most remarkable and valuable advantage is that indicated by its great output for deep therapeutic work, and also for instantaneous radiography. There is one note of warning, and that is that this tube gives little or no visible sign of fluorescence, so that extra precautions must be taken; otherwise, owing to its much greater output, a serious burn can be produced, the margin of safety being practically nil, whereas one cannot run the ordinary form of tube continuously with a heavy current.

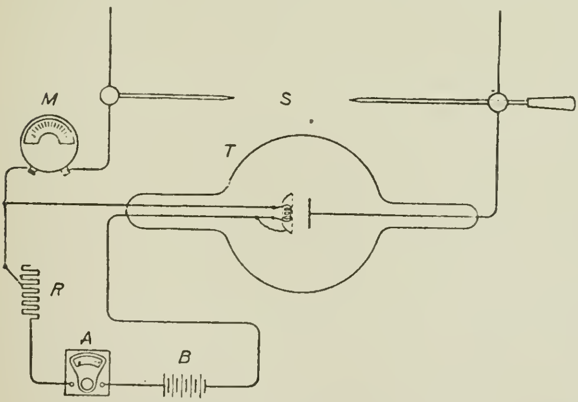


Fig. 49.—Diagram of connections for Coolidge tube.

S, Spark-gap.
M, Milliammeter.
B, Storage battery.
R, Rheostat for controlling current in the filament circuit.
A, Ammeter for measuring current in filament circuit.

Connections.—The accompanying illustration shows the tube properly connected to the storage battery and the terminals from the coil. *It must always be borne in mind that the entire battery circuit is brought to the full potential of the tube, and that it, therefore, has to be as thoroughly insulated* both from the patient and the ground as has the tube itself.

The full circuit is shown in Fig. 49, but the ammeter is not shown in illustration 48. As the diagram shows, the resistance is all in, and hence the filament temperature is lowest when the rheostat handle is pushed as far as possible away from the operator.

If the polarity of the machine is wrong, it will be shown by the fact that the milliammeter will register no current, regardless of how high the filament temperature may be.

The Battery.—A convenient size is a 5 or 6 cell (10 or 12 volt) 40 ampere-hour battery, and it will be found much more satisfactory if arrangements are made so that the battery can be connected either every night or else whenever not in use during the day, to the charging circuit. In some cases it will be found convenient to have the battery stand on the floor, while in others it may advantageously be placed higher up on a shelf. In the latter case it will be necessary to re-locate the rheostat on the back of the stand, so that the handle will point in the right direction. Both the rheostat handle and the cord attached to the pull switch (in the battery circuit) should be brought through the lead screen which protects the operator, and to a point within easy and *convenient* reach.

Method of Operating.—The technique of various operators and the sources of excitation vary so much that it is difficult to make very detailed suggestions. The following general considerations, however, may be of value.

The higher the filament temperature, the greater the discharge current.

The higher the voltage backed up by the tube, the higher the penetration.

A simple method for starting radiographic work with this tube is as follows :

Take a case, for example, where the operator has been setting his rheostat on the 10th button, and adjusting his tube to where it then draws 30 milliamperes. In this case, all that is necessary, with the Coolidge tube, is to set the rheostat on the 10th button, light up the filament in the tube, having the handle pushed as far away as possible, close the main switch, and pull on the rheostat handle until the tube is drawing 30 milliamperes. The main switch is then opened, and the operator is ready to make his exposure.

In other cases, the radiographer may be accustomed to adjust the tube by means of the milliamperemeter and the parallel spark-gap. This procedure can be applied equally well to the Coolidge tube, and will naturally be the one first used in all cases where the operator is not familiar with his machine. Knowing that he wants, for example, 20 milliamperes and a 5-inch parallel-gap, he will start with the battery rheostat handle pushed well away from him, and with his main rheostat set on a low button. He will then pull on the battery rheostat handle, and run up to higher buttons on the main rheostat, until the tube is drawing 20 milliamperes and backing up the 5-inch gap.

The tube may be safely run with the target at white heat. If excessively high energy inputs are employed, the tungsten at the focal spot melts and volatilises. This results in a sudden lowering of the tube resistance and in blackening of the bulb. The instability in resistance disappears instantly upon lowering the energy input, and no harm has been done to the tube, that is, unless it is to be used for the production of the most penetrating rays which it is capable of emitting. In this case, a heavy metal deposit on the bulb is undesirable, as it interferes with smooth running at such high voltages.

The tube should not be run with a voltage higher than that corresponding to a 10-inch spark-gap between points (that is, it should not be made to back up more than a 10-inch parallel-gap).

For long-continued running in an enclosed space and with heavy energy inputs, it will be necessary to provide some means of cooling the glass, as by a small fan or blower. The glass can, however, safely be allowed to get very hot. It is all right so long as it does not soften and draw in.

In running the tube on a coil, a valve tube should be used when heavy energy inputs are to be employed. So long, however, as the temperature of the focal spot is not made to approximate that of the cathode, the tube will satisfactorily rectify its own current.

The Coolidge tube is proving so useful in radiographic and therapeutic work that there is every indication that it may eventually displace most other tubes at present in use, and when improvements recently indicated by Coolidge are incorporated there is every probability that it will continue to hold the first place. In view of the likelihood of its general adoption by all workers it is thought advisable to give a full description of the construction of the tube, as it is only by a thorough understanding of its mechanism that its manipulation can be intelligently carried out.

The cathode is a tungsten filament forming a flat closely-wound spiral; this tungsten filament, consisting of a number of convolutions, is welded to heavy molybdenum wires, Fig. 50, these being in turn welded to a platinum wire. To ensure rigid support for the hot filament, the molybdenum wires are sealed directly into a piece of special glass which has the same coefficient of expansion as molybdenum. The outer end of the supporting tube is of soda glass like the bulb itself, and it is therefore necessary to interpose a graduated series of different kinds of glass to allow for the differences of expansion. A small glass tube surrounding one of the copper leads prevents short circuiting of the copper wires.

The tungsten filament which forms the cathode is heated by a current from a small storage battery, Figs. 48, 49. An ammeter and an adjustable rheostat in the circuit provide for the regulation, with accuracy, of the heating current between 3 and 5 amperes. This also illustrates the weak spot in the apparatus; variations in the battery from day to day require to be taken into account in the estimation of the heating current required to produce a ray of particular penetrative power. It is hoped that a more perfect method of heating the spiral will yet be devised.

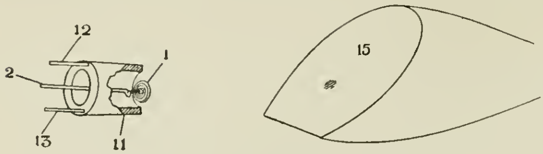


FIG. 50.—Diagram of cathode and anti-cathode of Coolidge tube.

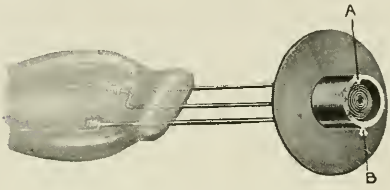


FIG. 51.—Cathode of Coolidge tube, mounted complete.

The focusing device consists of a cylindrical sleeve of molybdenum. It is mounted so as to be concentric with the tungsten filament, with its end projecting about 0·5 millimetre beyond the plane of the spiral. Two stout molybdenum wires support it, and these are sealed into the end of the glass tube, while the sleeve is electrically connected to one of the filament leads. This sleeve prevents any electron discharge from the back of the heated portion of the cathode in addition to its focusing action.

The anti-cathode or target serves also as an anode. It is a single piece of wrought tungsten welded to a cylindrical molybdenum rod, and supported by a molybdenum split tube. The split tube fits in a glass anode arm serving the double purpose of supporting the anode and conducting heat away from the cylindrical rod.

The bulb is made of soda glass and is about 18 centimetres in diameter.

The penetrating power of the X-rays is determined by the voltage across the tube terminals, that is, the penetrating power of the rays from the tube increases with the potential difference between the terminals of the tube.

This difference can be clearly shown by experimental results obtained when the heating current is kept constant and the potential increased step by step on the resistance of a high-tension transformer.

Characteristics of the Tube.—These require to be carefully considered if the best quality of work is to be obtained.

A. Unless the filament is heated the tube shows no conductivity in either direction.

B. The tube allows current to pass in only one direction. The tube is supposed to suppress any current passing in a direction which does not make the filament hot. It is therefore capable of rectifying its own current when supplied from an alternating source.

C. The discharge current is determined previously by the temperature of the filament in the tungsten spiral. The amount of discharge current which can be passed through the tube is determined previously by the temperature of the filament, and it responds instantly to changes in the filament temperature in either direction.

When the temperature of the filament is low, only a small number of electrons escape from it, and consequently only a small discharge can be sent through the tube. An increase in the voltage above that needed for this current causes no further increase in current. It simply increases the velocity of the cathode rays and hence the penetrating power of the X-rays.

Later improvements in the construction of this tube have been carried out and described by Mr. Coolidge in an article[1] published in the *American Journal of Röntgenology*. These are very great advances on the original tube, and it is possible that when the working conditions are better understood, even greater advances may be made in this tube and the technique of its use may become more elaborated. The chief aim of the work done, so far, has been to produce a tube which will give sharp detail in radiographic work. For this purpose the chief desideratum is that it shall give the greatest possible X-ray intensity from a given-sized small focal spot, for the use of a small focal spot imposes upon the tube a correspondingly small energy input limitation, and this extends the time during which immobility of the part to be radiographed must be maintained. To get the largest allowable energy input from a given-sized focal spot, the following conditions must be met :

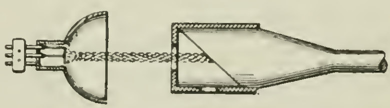
(*a*) The distribution of energy over the focal spot must be uniform.

(*b*) The heat must be removed from the focal spot as rapidly as possible.

Coolidge describes experiments carried out with this end in view. Acting on a scheme of Professor Eldon Thomson to rotate the target, he has constructed a tube which has been used experimentally. The target runs at 750 revolutions per second with the focal spot describing a circle three-quarters of an inch in diameter. Two and a half times as much energy for the size of the focal spot is thus obtained when compared with the stationary target.

For better definition in radiographic work the rays should all come from the focal spot. With the present type of test cathode tube there is a very considerable emanation of X-rays from all over the target. By experiments Coolidge has determined that the integrated value of the rays from half of the target surface, exclusive of the focal spot, is about one-sixth of the intensity of the focal spot. He further states that all the experimental work at present points to the fact that these distributing X-rays from the body of the target are caused by secondary cathode rays coming from the focal spot, which are prevented from going to the glass, as they do in the ordinary gas-filled tube, by a negative electrification of the bulb.

To reduce the intensity of this distributing factor a cylindrical hood or cap of molybdenum has been attached to the front of the target. (See Figure.)



The cathode rays enter this hood through a small hole in the front,

[1] "A Summary of Physical Investigation Work in progress on Tubes and Accessories," by W. D. Coolidge. *American Journal of Röntgenology*, December 1915.

and the X-rays emerge through a second hole in the side. The hood offers the following advantage :

It reduces the radiation from the surface of the target, exclusive of the focal spot, to about one-sixth (in the present design) of what it is without the hood. The advantage of this arrangement has been demonstrated by a number of experiments carried out by Coolidge.

Control for Coolidge Tubes.—The current required to operate a heating element in a Coolidge tube is obtained either from an accumulator or from a transformer. The disadvantage of the accumulator system is that the cells require recharging at intervals, and the output from the accumulator varies at different times according to whether it is fully charged or nearly run down. The better system is to employ a step-down transformer, which is operated from an alternating current supply, and is therefore particularly useful when working the high-tension transformer from a main alternating current. In those cases in which the transformer is worked from continuous current supply or an induction coil is employed, it is necessary to use a small rotary converter.

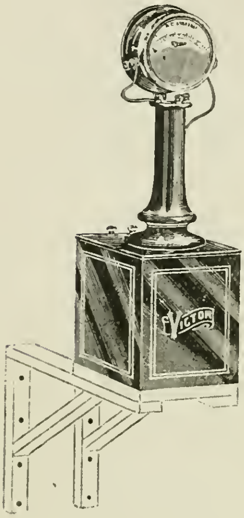


Fig. 52.—Victor Coolidge transformer, mounted on wall bracket. (Watson & Sons.)

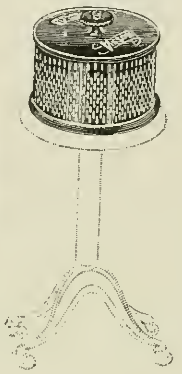


Fig. 53.—Coolidge control, with scale. (Watson & Sons.)

One of the great advantages of the transformer system of control is that a constant movement of the regulator is preserved throughout the entire current range ; in other words, the movement of the regulator for an increase or decrease of current, both minimum and maximum intensities, is uniform. With the battery system, when say 3 amperes are being employed in the cathode circuit, a fairly fine regulation is possible, but when the filament current is increased to between 4 and 5 amperes, the slightest movement of the regulator causes a distinct variation.

The Victor Coolidge control permits of a current variation of ·01 of an ampere and less, each scale division of the regulator representing ·01 of an ampere, which is the finest variation likely to be required for Radiography or treatment. The apparatus consists essentially of a transformer, amperemeter, control with scale, and suitable stand. A further advantage of this system is that there is no connection between the regulator and the high-tension current, so that the regulator may be mounted on a wall or on a suitable stand.

It is important that the regulator be provided with a compensating arrangement to avoid the line drop which occurs when operating both from the same alternating supply. The units on the control are calibrated by the operator in conjunction with the amperemeter for each particular circuit, as the resistance of different Coolidge tubes naturally varies.

The Hydrogen Tube.—The tube is completely exhausted of air, the gas molecules employed for the conduction of the current being pure hydrogen.

The tube is fitted with two palladium osmotic tubes, by means of which the vacuum can be raised or lowered at will.

One of these tubes is enclosed in a small auxiliary bulb, forming a reservoir of hydrogen more or less under pressure, the other is surrounded by a protective glass cup and exposed to the air. Both tubes are provided with an auxiliary terminal by means of which they can be heated to redness by the passage of the high-tension current, thus enabling the vacuum to be raised or lowered.

The vacuum is therefore more or less under the control of the operator,

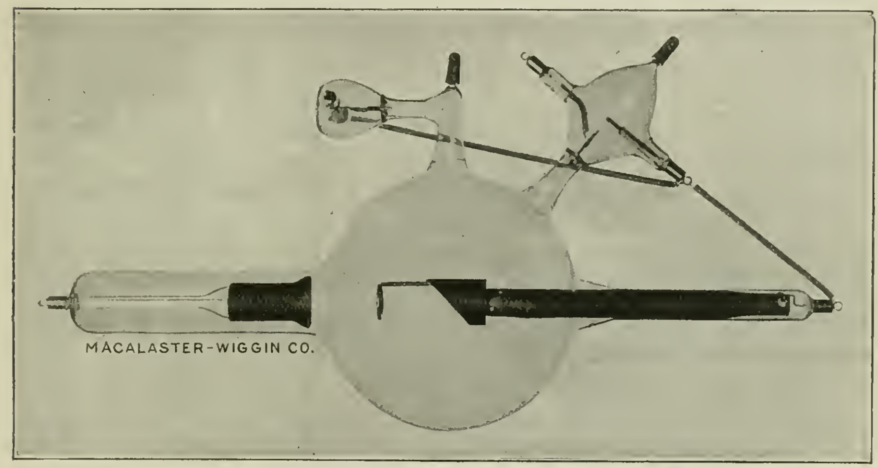


Fig. 54.—Macalaster Wiggin hydrogen tube. (Newton & Wright.)

it being possible quickly to adjust the penetrating power of the rays to suit any particular case under examination.

It is claimed for this tube that, unlike some other tubes, it is ready for all classes of work.

Should the vacuum be too low, it can easily be raised. Should it be too high, it may be lowered with equal ease, so that you are assured of a tube with the vacuum at the proper point for the picture that you want to make. The tube may be lowered to make a stomach picture, for instance, and within two or three minutes, or less, may be used for another exposure requiring much greater penetration. By the careful use of the raising and lowering devices you may regulate the tube at will and absolutely standardise your exposures.

The improved method of pumping and manipulating the tubes in the factory eliminates the foreign gases and gives an almost pure hydrogen vacuum in the tube.

There are other tubes made in America which differ from the types usually made on the Continent and in England, in that they are exhausted by a special process, and as no mercury is employed in the pumping it is impossible for mercury vapours to find their way into the tube ; this enables the tube to be exhausted " hard " in the first instance. The tube is hard from the beginning, and does not therefore require to be carefully worked up for radiographic or therapeutic work. It may be used at once for deep work. The tube may require to be regulated if it is too hard. These new tubes are fitted with a special form of cathode, which prevents the concentration of heat at the neck of the cathode. They are consequently not so liable to break down when overloaded.

The evolution of this type of tube in America is no doubt due to the fact that workers there are using more powerful apparatus for X-ray work, and have had to produce a tube which will stand up to the heavy currents generated by such apparatus.

The Production of X-Rays.—When a current of electricity from an induction coil is passed through an X-ray tube, a beam of cathode rays from the concave cathode is focused on the target or anti-cathode, the surface of which is inclined at an angle of 45° to the rays. The anti-cathode is usually made of a metal of high atomic weight, such as platinum, tungsten, etc. The anode and cathode are usually of aluminium ; from the point of contact of the cathode stream on the anti-cathode, X-rays are given out in all directions. X-rays are invisible, and do not make glass fluorescent. The pale-green hemisphere of fluorescence on the bulb is due to reflected cathode rays from the anti-cathode striking the glass of the tube. This may be clearly shown by the action of a magnet on the boundary of the fluorescence. X-rays are not deflected by the proximity of a magnetic field. The pressure of the gas in an X-ray tube becomes lower with use, and a device for softening the tube (*i.e.* raising the pressure of the gas in the bulb) is therefore usually provided. The higher the pressure the less is the potential required to work the tube, and the less the penetration of the rays. The X-rays produced and the condition of the tube are termed " soft " if the pressure of gas in the bulb is high. The lower the pressure the harder are the rays. The cathode of the tube is fixed just within the neck of a side tube to the bulb. As the exhaustion of the tube proceeds, the focus of the rays recedes farther and farther from the cathode, and may reach a distance of something like four or five times the radius of curvature of the cathode.

The relative positions of cathode and anti-cathode is a matter of experience with the maker. The anti-cathode is usually mounted a little out of focus to avoid its early destruction by fusion, the result of the extreme heat generated at the focus point. When sharp radiographic work has to be done the focus must be exceedingly sharp. Some makers turn out tubes with a very sharp focus, and excellent radiographs are obtained with such tubes. The drawback to the tubes is the comparatively short time they last.

The Anti-cathode of the X-Ray Tube.—The requirements of an anti-cathode intended for modern radiographic work are :

(1) A high atomic weight to secure a large quantity of rays.
(2) A high melting point to permit sharp focusing.
(3) A high thermal conductivity.

TABLE TO SHOW PROPERTIES OF VARIOUS METALS. (FROM KAYE.)

Metal.	Atomic Wt.	Density.	Intensity of Rod.	Melting Point.	Thermal Conductivity.
	0=16	Grms./c.c.	Pt=100	° C	C.G.S.
Platinum	195·2	21·5	100	1750	0·17
Iridium	193·1	22·4	98	2290	0·17
Tungsten . . .	184·0	19·3	91	3200	0·35
Tantalum . . .	181·0	16·6	90	2900	0·12
Copper	63·6	8·9	33	1084	0·92

Appearance of the X-Ray Tube in Action.—When the X-ray tube is connected properly one-half of the tube between the cathode and anti-cathode looks as if it were evenly filled with green light, the other half of the tube behind the anti-cathode remaining dark, because the anti-cathode acts as a screen.

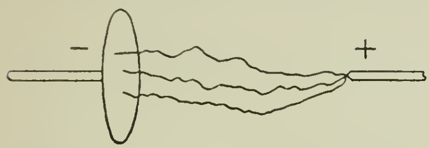


FIG. 55.—Connections of the X-ray tube to the coil, showing the route travelled by the spark when the point is the positive pole and the negative the plate.

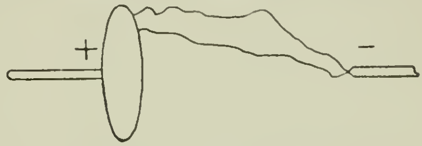


FIG. 56.—Connections of the X-ray tube to the coil, showing the appearance when the poles are reversed.

If wrongly connected there is an irregularly patchy fluorescence of the walls of the tube, and rays appear at intervals which change considerably according to the amount of current passing through the tubes.

For the appearance of the X-ray tube when correctly and incorrectly in operation, see the coloured plate.

The important thing to remember is first of all to ascertain the polarity of the coil. This is done by testing with the spark-gap.

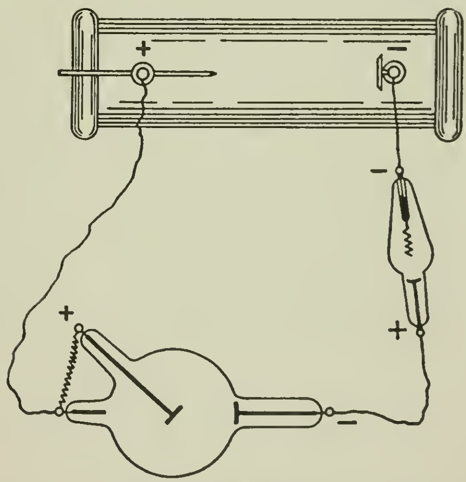


FIG. 57.—Connection of X-ray tube to the coil, showing coil and connections to tube. A valve tube is inserted on the negative pole.

Selection and Regulation of X-Ray Tubes—Little need be said on this point. As nearly all the tubes on the market are now good, the particular type selected depends to a large extent upon the operator. When possible a number of good tubes should be kept in constant use. A tube which is in good condition and has a sharp focus should be reserved for radiographic work ; for therapeutics a tube with a diffused focus is better than a sharp one because it will last longer. This requires to be taken with reserve. Some workers prefer to use a sharp focus for therapeutic work. It may be that the sharp focus of the cathode stream upon the anti-cathode may generate a beam of X-rays of particularly good therapeutic value.

Unless for special purposes it is always better to purchase tubes of a medium vacuum, inclining towards the soft side. A tube of large diameter, 7 or 8 inches, will continue to keep good vacuum longer than a smaller tube. For heavy currents, either in radiographic or therapeutic work, the larger tube will in the end be found most economical.

The chief advantage of having several tubes in use is that the very soft tube may be used for lighter work and gradually worked up for thicker parts of the body. Then with about half a dozen tubes all parts of the body may be radiographed with a tube in proper condition for the part. New tubes are generally soft and require to be gradually worked up in hardness before they can be used for the deeper parts of the body. It is a good plan to reserve new tubes for short exposures of the thinner parts such as the hands, ankles, and feet. After a few weeks of such work a new tube may then be used for the knees, shoulders, and elbows.

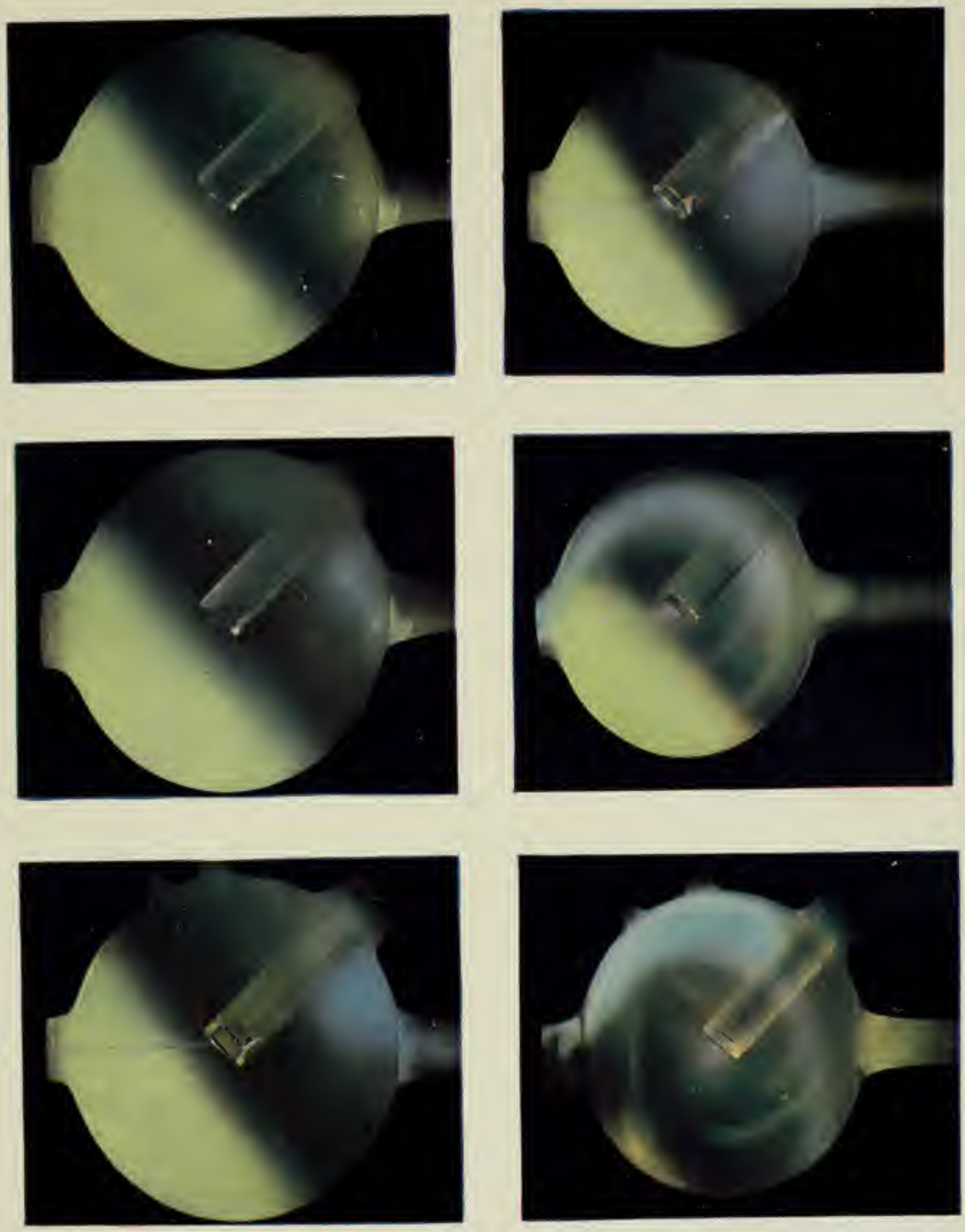
Later, when the tube has become seasoned, it can be used for the longer exposures required for radiography of the kidney areas, spine, and skull.

A new tube should never be overrun, that is, long exposure with large currents should not be used, because if they are, the vacuum may be hopelessly reduced, and the tube will then require to be re-exhausted. Once a tube is seasoned it will maintain its vacuum and degree of hardness for long periods, and may be used for hours daily. The amount of usage to be got from a tube which has been thoroughly seasoned is surprising.

Sometimes a tube after repeated short exposure may not harden. A good plan is to run such a tube for half an hour to one hour on the minimum current available. A $\frac{1}{4}$ milliampere through a tube for several runs of that duration may succeed in bringing it into a working condition. It should be treated carefully for several weeks.

The majority of tubes after prolonged use tend to harden. This natural hardening from use may be combated in several ways. The best of all is to regulate the tube by varying the intensity of the current passing through the bulb. A tube too hard for the object we desire to examine can be brought back to the proper degree by allowing a fairly strong current to pass for several minutes. If the current used is not sufficient for this purpose, pass a very heavy current for a moment.

A time comes with all tubes when we must use the mechanical regulator, the same remark applying to valve tubes. The form of regulator varies with the make of the tube, and all require some understanding before we can properly use them. In all cases it is better to begin reducing the tube with a minimum quantity of current and a fairly large interval of space



1 4

2 5

3 6

Appearances of X-Ray Tube in Action

Reproduced from coloured drawings kindly lent by Mr. C. Andrews.

1. Hard Condition.

Note absence of blue gas in region of anode, also sharply-cut upper limit of green hemisphere. The condition indicates absence of reverse current.

2. Normal Condition.

Note faint blue cloud in region of anode. Reverse current is practically absent.

3. Soft Condition.

Faint blue cloud has increased and is now very noticeable. The green hemisphere is still sharply cut, but a distinct cathode stream appears between the cathode and anti-cathode.

4. Very Soft Condition.

The faint blue cloud has spread farther than in the preceding figure, and the cathode stream is more evident.

5. Reverse Current in Circuit.

The appearance of the tube is changed entirely. The hemisphere has lost its sharply-cut appearance and is irregular. The faint blue cloud, due to gas in the region of the anode, has also changed, and the upper hemisphere of the tube is occupied by irregular rings.

6. Polarity Reversed.

The cathode has become the anode and *vice versa*. Note the stream of gas at the back of the tube and the bright spot on glass wall opposite to the anti-cathode; also the absence of green hemisphere.

between the cathode terminal and the regulating rod. The distance can easily be diminished, the important point being not to overdo the reduction.

When radiographing some parts of the body we estimate the degree of hardness of the tube by one of the methods enumerated, *i.e.* alternative spark-gap, Wehnelt radiometer, Benoist scale, and then place the regulating rod of the tube at the half distance of the spark-gap required, and allow current to pass through the tube. Sparking at once goes on between the two points, and some gas is liberated in the glass cylinder at the end of the regulator. The gas passes into the interior of the bulb, the shadow on the screen is altered, and the sparking ceases. Make sure that the regulating rod is taken well away from the cathode before actually making the exposure, as a good tube may be hopelessly ruined if this simple precaution is not taken.

The various devices for regulation of the vacuum of a tube are shown in the illustrations. The best of all, and one which gives the operator a perfect control over the tube when working, is the air valve of Bauer. This valve can be attached to any tube or valve, and is undoubtedly a great help to the operator. In using it, care should be taken not to introduce air too rapidly, and to introduce just sufficient to maintain the balance of the vacuum. One can readily judge of the action if the tube is observed carefully while reduction is going on.

The tube may, however, get too hard for regulation. It is then a good plan to transfer that tube to another apparatus of greater strength. A tube which has hardened on a mercury break may act perfectly if placed on an installation with an electrolytic break. The primary current is much greater in the latter case, the secondary is greater, and there is more heat generated in the tube, with the result that the vacuum tends to fall and the tube to soften. A hopelessly hard tube should be put away for several weeks in a warm corner of the X-ray room or placed in an oven for several hours. This may help to reduce it sufficiently to allow it to be used, and then by regulating the current carefully it may be possible to use it for some time.

Explanation of the blackening of an X-Ray Bulb, and its effects upon the behaviour of the Tube.—With continued use the X-ray bulb becomes blackened on its inner surface. Two main causes are answerable for the blackening :

(1) The disintegration of the anti-cathode whilst acting as cathode during the passage of the inverse current, and also of the cathode during the direct phase.

(2) The volatilisation of the anti-cathode due to its high temperature under reduced pressure.

The effects upon the behaviour of the tube when in action are :

(*a*) The deposit tends to increase the resistance of the tube to the discharge.

(*b*) It accelerates the absorption of the residual gas.

(*c*) The discharge tends to spark irregularly along the walls of the tube instead of through the gas in the tube. This may lead to puncture of the tube.

(*d*) The thin film of metal deposited on the glass absorbs the softest X-rays.

When a tube has been used for a long time and gets too hard for work it is better to sacrifice it altogether. Re-exhaustion and remaking of the tube costs in many instances nearly as much as a new one, and these re-exhausted tubes are rarely so reliable as a new one. Consequently it is better to break up the tube, and have the valuable parts used for the construction of a new tube.

There are many other points in the management of the X-ray tube which must be learned as the result of experience. The fact must always be borne in mind that it is the tube which is the determining factor in radiography, and too great care cannot be taken of the X-ray tubes when in or out of use. Powerful currents if instantaneous do not harm the tube, but if prolonged the vacuum is lowered and the tube ruined. The quicker the exposure the more useful is the resulting radiograph likely to be. It should be noted that when a tube is used for all purposes, *i.e.* screening and radiography with heavy discharges, the balance of the tube is often seriously disturbed, regulation being then a matter of increasing difficulty. It is a good plan to keep one tube for screening and another for heavy work. The Coolidge tube is an exception to this rule on account of its extreme adaptability.

The effect of the most powerful impulse on the tube is hardly perceptible, a current of 100 milliamperes or more passing through a tube for the $\frac{1}{100}$ of a second leaving hardly any trace on the anti-cathode. This current may be employed on the cheapest form of tube without injuring it. There is, however, a tendency for a part or the whole of the current to arc round the tube if the vacuum is too high, consequently tubes with long stems or necks are necessary if hard ones are to be used. With these powerful impulses the soft tubes give the best results.

While for the taking of instantaneous pictures the most powerful installations are the best, it must be pointed out that quite good rapid radiographs can be produced by the use of installations of moderate power, provided the operator knows the apparatus he is using, and particularly if he possesses that knowledge of the X-ray tube which is, after all, the chief essential.

The Manipulation of the X-Ray Tube.—The X-ray tube should whenever possible be placed at a distance of at least 6 or 7 feet from the source of energy (coil, etc.). If used within this distance there is a probability that the magnetic field may affect the cathodal stream, and thus alter the focus of the tube.

When the tube is supported by any form of clamp, the latter should grip the cathodal neck, below the level of the concave cathode, this being the strongest part, and should not clamp it too tightly. Before turning on the current, the tube should be carefully dusted, or dried if there is any moisture present.

The positive pole of the coil or other apparatus should be connected by well-insulated cables to the anti-cathode of the tube, and the negative pole to the cathode. It should be seen that all loose wires or metal fittings are quite clear of the tube.

When using heavy currents the regulating wire should be placed well back from the cathode—say at a distance of 6 or 7 inches,—otherwise sparking may occur and the tube be rendered too soft for use. There are exceptions to this rule in the manipulation of those tubes which work best with the regulator at a fixed distance from the cathode, according to the hardness of the particular tube and the purpose for which it is being used; but even then care must be exercised when using very heavy currents.

The current may now be switched on, starting with all resistance in, and gradually cutting this out until the tube fluoresces brightly and steadily. If the tube is inclined to spark over, bring the regulator to within a distance of 4 or 5 inches of the cathode, so as to provide a kind of safety-valve action. This will allow of the sparks passing between the regulator rod and the cathode, and tend to reduce the vacuum of the tube and so avoid the tube becoming punctured.

Before deciding that a tube needs regulation, allow it to run for a minute or two to give it an opportunity of finding its balance. Often it will be found that a tube so treated will settle down after a short run. In other words, do not be in too great a hurry to regulate the tube. A little more or a little less current passing for a short time may successfully regulate the vacuum and allow of good work being done.

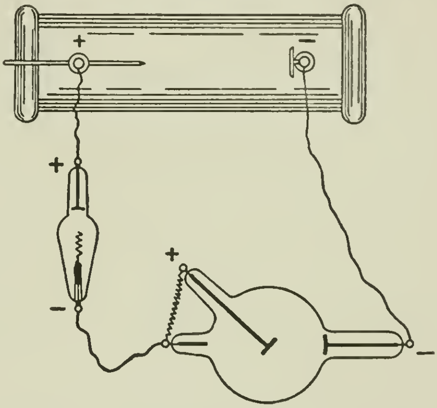


Fig. 58.—Connection of the X-ray tubes to coil. Valve tube on positive pole.

If regulation is necessary, proceed to adjust the regulating rod at a distance which will allow sparks to pass between the rod and the cathode until the tube works smoothly, and then remove the regulating rod away from the cathode and test the tube again.

Hardening the tube can only be satisfactorily done by gradually working a soft tube up through using it for very light work or for superficial X-ray treatment until it attains the necessary degree of hardness. Hardening by means of reversing the current is a method which should never be resorted to. When a tube becomes hopelessly soft, the only satisfactory thing to do is to have it re-exhausted.

When work is finished, if the tube is not kept permanently in position, it should be removed from its shield with great care, particularly while warm. If possible, it should then be placed upon a padded rack.

Description of Methods used for Regeneration of the Vacuum of the X-Ray Tube.—All tubes (excepting those of very simple construction) are fitted with a device for lowering at will the vacuum or internal resistance of the tube. The provision of this regulator materially increases the life of the tube. It should, however, be always borne in mind that regulation is to be regarded as the ultimate process, and not as incidental to the working of the tube.

The number and variety of the regulators of X-ray tubes is a striking demonstration of the fact that the perfect regulator has yet to be introduced. Most of the present-day regulators are efficient up to a certain point. A few of the most commonly used will be described.

The Mica Regulator.—This consists of a small auxiliary chamber, in which is placed an electrode supporting a series of discs of mica. Facing the discs is a small metal knob which has no utility other than that of preventing a possible puncture of the tube, while regulation is taking place. Attached by a hinged cap to the mica electrode is a wire which may be brought into contact with the cathode terminal of the tube.

The method of lowering the vacuum of the tube is as follows: The

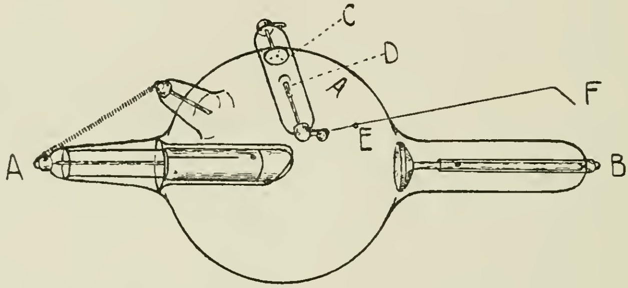


Fig. 59.—Tube fitted with mica and carbon regulator. (C. Andrews.)
A, Anti-cathode. C, Mica disc. E} Wire.
B, Cathode. D, Carbon. F}

jointed arm, E F, is moved (by means of a piece of wood, glass, or other non-conducting substance) towards B for a few seconds, whilst current is passing through the tube, when sparks should pass between F and B. The passage of the current between the latter two points (as shown by the sparking) results in the partial suspension of the current from its normal path; and during the flow of the current through the electrode in the auxiliary tube, a small quantity of gas is liberated, with the consequence that a reduction in the vacuum takes place. When this has been achieved the sparking will automatically cease, the resistance of the tube itself having become less than that of the gap F B. The wire F should now be thrown well back, and the tube run cautiously for the first few minutes after regulation.

The regulation of the tube during use may be made automatic, if desired, by placing the wire F at such a distance from B that sparking (with consequent regulation) takes place whenever a certain degree of vacuum is attained. This distance may easily be determined by experiment with the individual tube in use.

In the case of a tube which fails to regulate by the above method, it is permissible to remove the cable from the cathode and attach it to the loop E. The current should now be passed with extreme caution, the pressure being very carefully increased until the gas is expelled from the mica.

In order to appreciate the degree to which regulation is taking place, the mica disc should be carefully watched while the shunt circuit is established. It will be seen that the mica shows little flecks of red here and there, and when these appear, it is a sign that gas is being expelled. The time during which the current should be passed through the regulator depends obviously upon the degree of hardness of the tube, and the amount of softening which it is desired to attain ; but in any case it is wiser to switch off the current as soon as the fiery appearance is seen in the mica, swing back the regulator wire, and test the tube ; and then to repeat the process of regulation if necessary.

The regulator shown is merely a variation of the standard mica pattern, and is fitted to some smaller tubes on account of its greater convenience where a 125-mm. bulb is employed. The mechanism is the same, but in place of the hinged wire, a shaped wire is fitted on a spring and pin bearing. Normally this wire rests in the position illustrated. To effect the softening, the wire is tilted with a piece of glass or wood until F B are in contact, when the effusion of gas from the mica takes place.

Larger models are fitted usually with a *double* regulator, viz. carbon and mica. This consists of a chamber exactly similar to that described above, excepting that, in place of the small metal knob, there is fitted an electrode carrying a cylinder of carbon. This is capable of giving off gas in exactly the same way as does the mica disc ; and so, in this double regulator, one has two supplies of gas upon which to draw. By means of a thumbscrew the regulator wire can be changed from one side of the regulator to the other, so that when one source of gas is exhausted, the second may be brought into use. The carbon regulator is operated in the same way as the mica, but it should be noted that there is no " fiery " appearance with the former, and also that the carbon works rather more freely than the mica. The appearance of the tube must then be taken as the guide to the necessary degree of softening. Care should therefore be exercised in order to avoid over-regulation.

In the ordinary way, a current of 1 or $1\frac{1}{2}$ milliamperes will cause the standard regulator to work in a few seconds, but in some cases, and especially when the regulator has been much used, a greater current may be necessary in order to heat the carbon or mica sufficiently. Experience will demonstrate this. The gases which are supplied by it to the tube allow the latter to remain constant and steady.

The regenerating arrangement with which some tubes are provided is constructed on the principle of osmosis. The metals of the platinum group, especially palladium, have the peculiarity that they allow hydrogen to pass while incandescent. A tube of palladium, closed at one end and open at the other, is sealed into the neck of the tube. To protect it against accidental damage it is covered with a test tube, which can be taken off. When the tube has become too hard, remove the test tube and apply a spirit flame for a few seconds to the palladium tube till it is dark red. The hydrogen contained in the spirit flame penetrates into the inside of the tube, and makes the tube softer. The flame must not be brought near the point where the metal is sealed into the glass.

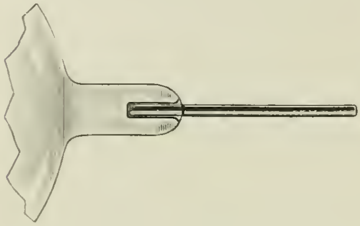


Fig. 60.—Osmosis tube for admitting hydrogen into an X-ray bulb. (C. Andrews.)

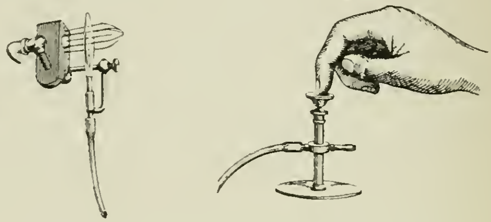


Fig. 61.—Showing method of controlling osmosis regulator from a distance.

Instead of a spirit lamp a gas jet may be used ; the jet is fixed close to the osmosis regulator, and, by means of a length of rubber tubing connecting the two points, the supply of gas to the jet can be regulated from a distance (see Fig. 61).

After the tube has been regenerated time should be allowed for complete cooling before it is used again. It is advisable to bring the tube to the desired degree of softness each time before it is used, and only to heat the extreme end of the palladium tube.

The Bauer Air-Valve Regulator.—Another form of regulator is the

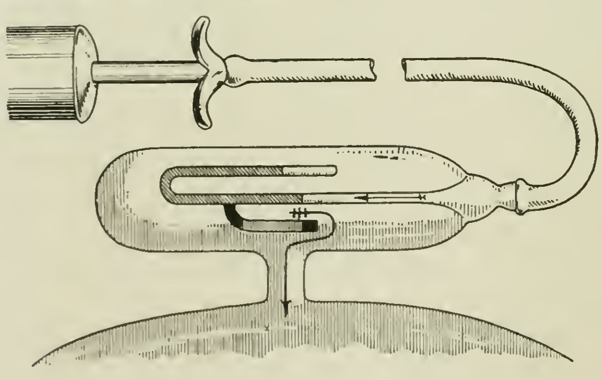


Fig. 62.—Bauer air-valve. (Favre.)

air-valve invented by Mr. Heinz Bauer. This consists of a delicately constructed valve, closed by a column of mercury, and fitted with an air filter. By means of a small hand pump and an india-rubber tube, the column of mercury is depressed so as to open a very small aperture, through which a minute quantity of air is thus allowed to pass. The mercury rises almost immediately, and the opening is again sealed, the vacuum of the tube having meanwhile been lowered by the admission of the air. If desired, the Bauer valve may be worked with a long rubber tube, thus allowing of regulation taking place from a distance, and while the tube is actually running.

Gundelach Regulator.—Another very good regeneration apparatus may be described.

This arrangement consists of a little condenser which is made in the form of a cylindrical glass tube covered with an imperfect conductor of electricity. By special treatment this conductor is made to absorb a large quantity of gas. It is then covered with a second glass tube, and both cylindrical glass tubes are so treated that they cannot be pierced by a spark.

When the tube has become too hard, put the wire *b* of the regenerating arrangement in contact with the metal cap *d* of the tube. The other wire *a* has to be so far from the metal cap *c* that a shunt-spark passes. This shunt-spark should be half as long as the equivalent spark of the Röntgen

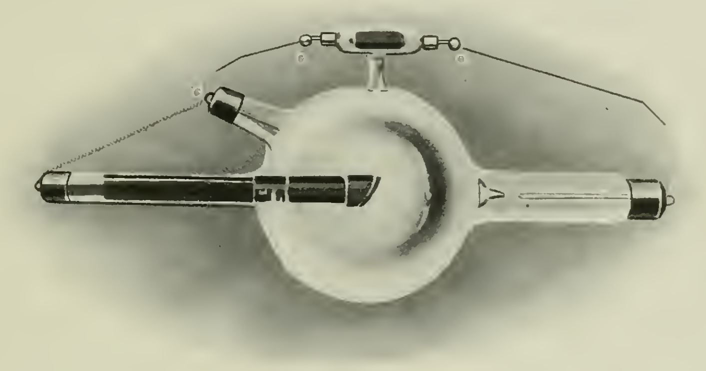


FIG. 63.—Gundelach tube with regenerator. (Siemens.)
a, Wire. *b*, Wire. *c*, Metal cap. *d*, Metal cap.

tube after regeneration, because the resistance of this regenerating arrangement is considerable. The current produces some gas from the substance of the regenerating arrangement, and after a few minutes the tube will again fluoresce regularly. The regeneration, however, is only completed when the shunt-sparks have ceased to pass. After regeneration turn back both wires. This new regulator will work easily even when the resistance of the tube has become so great that no electric current will pass through the Röntgen tube.

This arrangement has the great advantage that owing to the two conductors being separated by a glass tube, the gas is set free uniformly from all parts of the conductors, and the whole of the gas contained therein, which is considerable, can be utilised.

In order to obtain good pictures it is generally necessary to regulate the hardness of a tube each time previous to using it; whenever possible this should be done by varying the current passing through the tube until the correct degree of penetration is obtained.

Suppression of Reverse (Inverse) Current

The reverse current is obviously a great inconvenience and must be got rid of if good negatives are to be obtained. It is possible to keep it down to a minimum by using a low voltage, a high self-induction, and a low frequency in the primary coil; but if intense discharges are required we cannot suppress it entirely in this way, and other means must be adopted.

Valve tubes or spark-gaps are frequently connected in series with the X-ray tubes.

In a **Spark-gap** the current can discharge easily between a point and a plate if the point is the positive pole, but it does not do so if the point is the negative pole. It is possible, then, to create an impediment or resistance to the current in one direction only, whereas the passage is left free in the other.

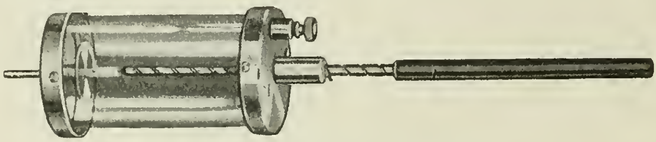


FIG. 64.—Spark-gap. (Siemens.)

There are many types of **Valve tubes,** the most commonly used being the single valve tube, but the triple valve tube is also used.

The nature of reverse current has already been explained. In all coil outfits this has to be checked. It is possible by a careful adjustment of primary current, interrupter, and tube, to cut this down to a minimum, but the slightest disturbance of these factors gives rise at once to a percentage of inverse current, which, if allowed to remain, has a deleterious effect upon the tube and tends to harden it. Should it become very hard the persistence of inverse current with strong currents in the primary leads to damage of the tube; sparking takes place, and the tube is punctured.

It is generally appreciated that the current which is utilised in the production of X-rays is that which is passing when the current is breaking, *e.g.* when the magnetic field is at the point of collapse, and it is the endeavour to obtain a maximum tension at the moment, and to relieve or "break" such tension with sufficient speed and completeness, that gives rise to the constant alterations and improvements—real or fancied—in modern medical electrical apparatus. The more complete the saturation of the induction coil, and the more suddenly the saturation can be "vented," as it were, through the secondary circuit, the more efficient (other factors being equal) the phenomenon of the Röntgen rays produced.

On the other hand, the current which is passing when the current is "making," *e.g.* when the cycle of the magnetic field is first commencing in the primary of the coil, is flowing in a reverse sense to that of the current at "break"; and it can therefore be seen that if this current is allowed to flow through the X-ray tube, it cancels, as it were, a portion of the "breaking" pressure equal to its own. Now, the result of this is not only a loss of efficiency in that it is a loss of working current: the effects are, unfortunately, more far-reaching than that, the X-ray tube becoming irretrievably damaged. In the first place, the actual passage of current in the "reverse" direction through the tube means that the anti-cathode, or positive pole of the tube, becomes, for an instant, cathode, and *vice versa*. Now, it is an established fact that the cathode electrode breaks up much more freely and quickly than the anti-cathode, and for this reason the cathode is always made from aluminium, which is less destructible in this sense than any other metal. But if the current is reversed, and the "cathode" is, for the moment, the copper "anti-cathode," the destruction is much more rapid, and particles of metal are torn off from the surface.

The fragments of copper, tungsten, etc., thus detached are projected with enormous rapidity towards the wall of the tube, to which they adhere, forming a thin metallic coating, particularly on the back zone of the bulb (*e.g.* behind and above the plane of the surface of the target). The result of this coating of metal is to absorb all the free gas in the tube, and is the explanation of an old blackened tube remaining often dead hard, however much it may be regulated or re-exhausted. The blackening described above must not be confused with the violet coloration *in front* of the plane of the target, which latter is a normal condition in all tubes after use, and which is free from objection.

The second ill-effect is that of overheating. If the usual form of milliamperemeter, known as the "moving coil" type, be employed, its reading is that of the difference between the "correct" and "reverse" currents. For example, supposing the current in the right direction to be equal to 2 milliamperes, and that in the wrong or reverse direction to be equal to 1 milliampere, the milliamperemeter would indicate 1 milliampere. But although this would be accurate so far as the measuring of the current itself went, it must be remembered that the *heating* effect of an electrical current increases as the square of the amperage. So that, although the operator may say, "The tube is all right; it is taking only 1 milliampere," we are subjecting it to the strain of 3 milliamperes so far as heat is concerned, viz. *nine times* the heat of a real 1 milliampere current. As has already been pointed out, it is mainly the heat which destroys the balance of the vacuum of the X-ray tube.

It is admittedly a very difficult matter to construct a modern installation which shall be free from reverse current, particularly as with the higher amperage which is demanded for rapid work, high voltages must also be employed, and the greater the voltage the greater the reverse discharge. The only means, therefore, of combating the evil is to introduce some device which shall "rectify" the discharge, *e.g.* eliminate the reverse current while interfering with the proper current as little as possible.

In order to effect this, many contrivances have been tried, notably a simple "spark-gap" and various forms of mechanical rectifiers. The most usual and most efficient method is, however, the valve tube, a vacuum tube which permits the current to pass unobstructed in the right direction but which should suppress absolutely the reverse or making current.

Single Valve Tube.—This valve tube, owing to its special construction, is much less inclined to become hard than the simpler types of valve tubes. It is fitted with the new regenerator so that it can be maintained at a uniform degree of softness ; this should be maintained at about 16 mm. equivalent spark-gap. When the tube requires regenerating one wire should be con-

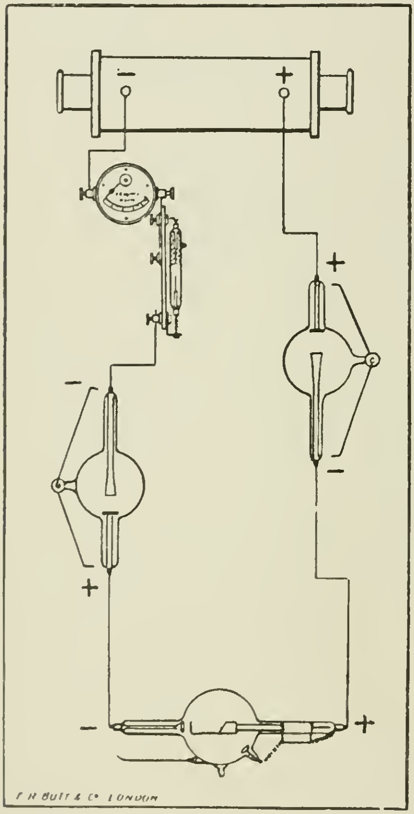


Fig. 65.—Correct method of connecting valve tubes in circuit.

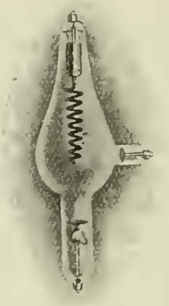


Fig. 66.—Single valve tube. (C. Andrews.)

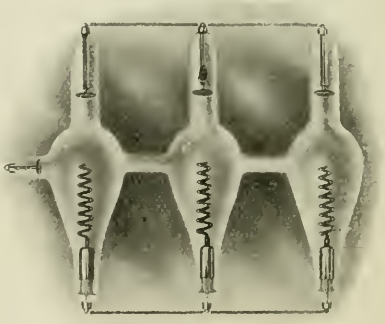


Fig. 67.—Triple valve tube. (C. Andrews.)

nected to the anode cap (positive), and the other held at a distance of about 5 mm. from the cathode cap (negative). As soon as the tube shows a white foggy light the regeneration is finished.

Formerly when it was desired to rectify on higher voltages, or while using heavy currents, two or more valves were placed in series ; but a difficulty then arose by reason of the fact that such valves did not always increase in hardness to the same degree, and it was therefore almost impossible to maintain an efficient rectification, and, at the same time, to pass the full amount of current needed. In order to overcome this trouble a "double" valve was designed, consisting of two bulbs and sets of electrodes, each exactly similar to one single valve, but joined together in such a manner that one vacuum is common to both chambers. The latter are then connected in parallel, and placed in series with the X-ray tube, the result being that the backward resistance is doubled, the current flowing between the two sets of electrodes. With such a double valve, complete rectification on voltages up to, say, 200 is obtainable.

The Triple Valve is constructed similarly to the foregoing, but has three intercommunicating chambers, and is intended for use on the highest voltages and for the heaviest discharges.

Valve tubes may be had either of clear glass, of blue, or of a deep amber colour. The latter is preferred by many workers, as the colouring serves to disguise the fluorescence, and thus permits of a better judgment of the condition of the Röntgen tube itself.

High-tension Rectifier.—A different form of valve is that known as the high-tension rectifier. It consists of a long aluminium funnel and a curved mirror, the bulb being spherical, and of a diameter of approximately 18 cm. This form of valve is very efficient, even on high voltages, but it has a tendency to increase in vacuum somewhat rapidly. For this latter reason an osmosis regulator is provided, so that regulation is possible as often as desired.

The Asta Valve Tube (for currents up to 30 milliamperes) is an American

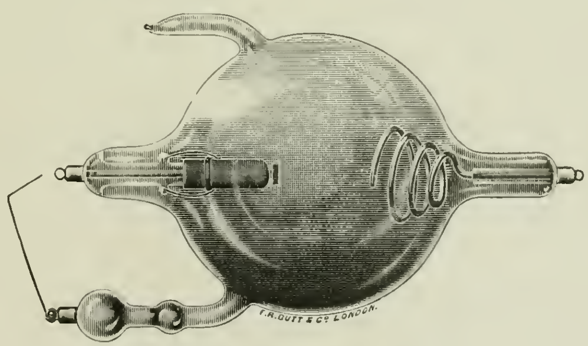


FIG. 68.—The Asta valve tube. (F. Butt & Co.)

tube fitted with regulating apparatus and suitable, as indicated, for heavy currents. This valve should be set with a spark-gap of from 1½ to 2 inches. For arrangement in circuit see Fig. 69.

French Type.—Yet another form is that known as the "French type," which is very similar to the single valve. It has, however, in place of the plate anode, a thin pin with a slightly flattened head, and the neck of the tube surrounding this is of much smaller diameter than in the other cases. The action of this valve is very perfect, complete rectification being obtained without any appreciable loss of current. The French pattern is, however, rather more delicate than the others, and also tends to go up in vacuum rather quickly. The provision of an osmosis regulator permits, however, of the latter trouble being overcome.

The Oliver Lodge valve tube is often used. It has the disadvantage that it cannot be regulated, but it is claimed for it that it does not require regulation. This claim is open to question. When it is necessary to check the reverse current which is found when very heavy discharges pass through a tube a number of these valve tubes may be placed in the circuit.

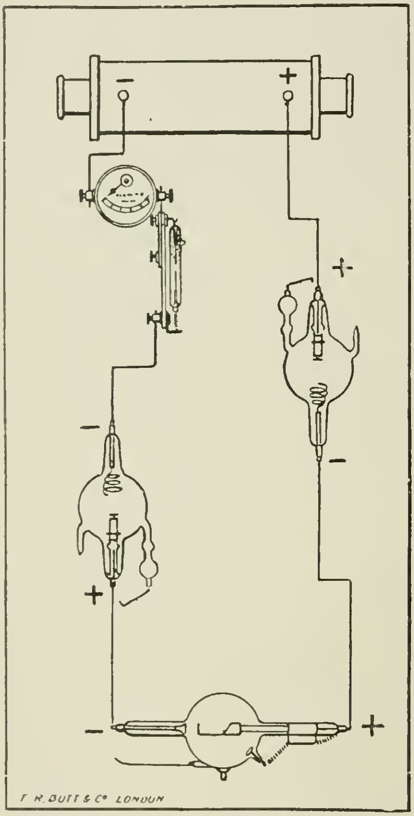


Fig. 69.—Correct method of connecting the Asta valve tube in circuit.

Fig. 70.—French valve. (C. Andrews.)

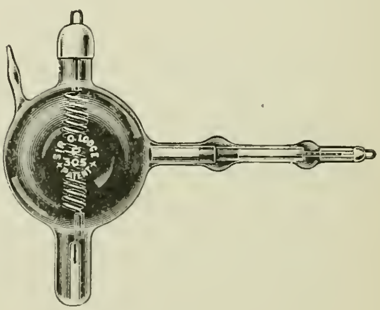


Fig. 71.—Oliver Lodge valve tube. (A. C. Cossor, Ltd.)

Regulation of the Valve Tubes.—The regulation of valve tubes is effected in a similar way to that of X-ray tubes, according to the type of regulator in use. In the case of the mica or carbon patterns, the lead which is normally attached to the anode should be attached to the ring of the regulator, and current passed until the blue appearance has been restored to the valve tube. The lead must then be reconnected to the anode terminal.

Valve tubes should never be worked "hard." An intermediate vacuum, giving a Geissler discharge in the body of the tube, with a slight apple-green tint round the spiral base, will be found best. Do not forget, also, that a "hard" valve tube may be emitting an appreciable quantity of Röntgen rays, with a consequent need of protection for the operator.

Bauer Air-valve.—The latest improvement in the valve tube is the introduction of a Bauer air-valve for the regulation of the vacuum. This is very useful and easily handled by the use of a small hand-pump, a long rubber tube allowing of regulation from a distance.

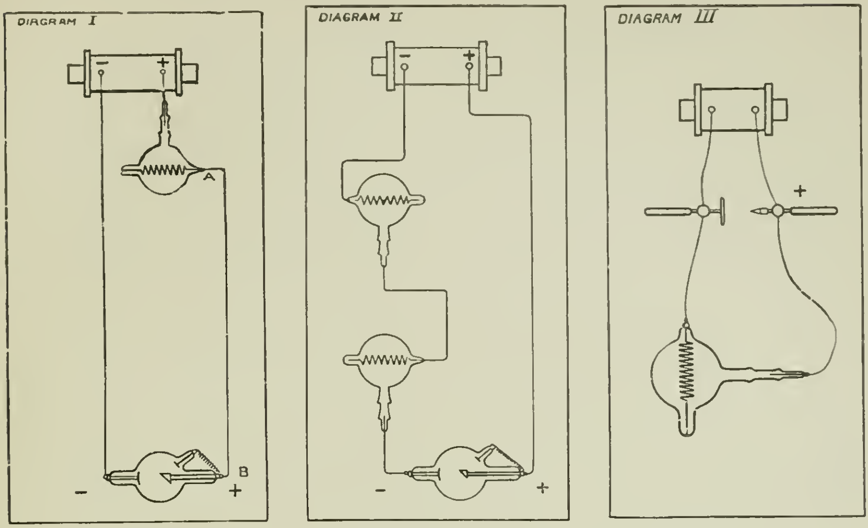


Fig. 72.—Arrangement of valve tubes in circuit. (A. C. Cossor, Ltd.)

Diagram I. shows the correct method of connecting for single valve tube.
Diagram II. shows the correct method of connecting for two valve tubes in series.
Diagram III. shows the correct method of connecting in order to ascertain equivalent spark length or to work up (to harden) the valve tube.

When intensive currents are used it may be necessary to put a valve tube on each pole or even to have 6 or 8 valve tubes in series. By using valve tubes the amount of inverse current can be practically abolished when

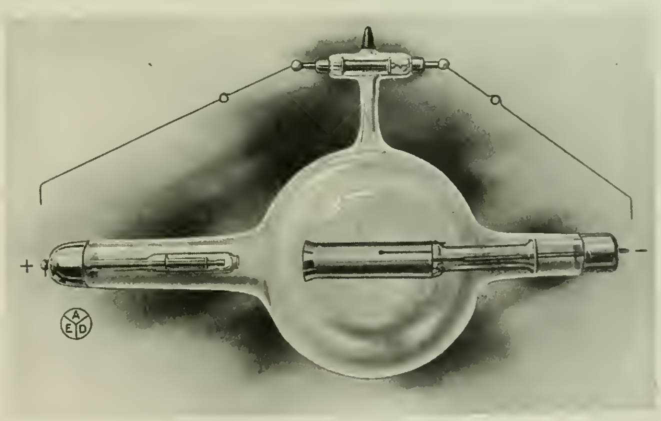


Fig. 73.—Zenith valve tube. (A. E. Dean.)

medium currents are employed, but when very heavy currents are used it is not possible, or hardly ever possible, to abolish it.

There are several other varieties of valve tube of more recent construction. The various types described are useful on installations of medium power, but if they are used on the more powerful installations of recent date, they soon begin to vary in hardness, and add considerably to the difficulties of the radiographer. This is particularly noticeable when the installation is used alternately for short exposures and long ones. The balance of the valve tube is disturbed, and it will require almost constant regulation. It should be pointed out that when valve tubes are used they require nearly as much regulation as the X-ray tube. When the X-ray tube is known to be right and the results are not satisfactory, attention should be paid to the condition of the valve tube.

Method of Detecting Reverse (Inverse) Current.—A good guide to the presence of reverse current is the appearance of the tube in action,

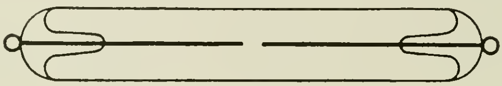
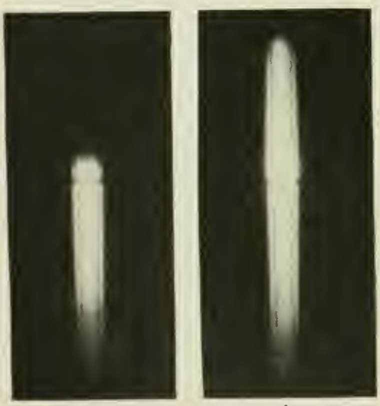


FIG. 74.—Oscilloscope tube. (Siemens.)

rings then appearing on the aspect of the tube behind the anti-cathode, and the green light in front not being so clearly cut as when there is no trace of reverse current.

The continued presence of reverse current leads to changes in the condition of the tube. It gradually hardens, and this change in the vacuum may reveal itself by a variation in the sounds produced when in action.



a *b*

FIG. 75.—Oscilloscope tube in action. (Schall.)

a, The appearance of a tube with the current passing in the right direction with a trace of reverse current.

b, The appearance with the current passing in both directions in almost equal proportions.

The best method of detecting reverse current is by the use of an oscilloscope tube. The construction of such a tube is worthy of description. Two aluminium wires, separated by a small gap, are enclosed in an oblong glass tube of low vacuum, and the wire connected with the negative pole becomes, when the current passes, surrounded by a violet fluorescence. If the current discharges in one direction, only one of these wires shows the violet light, but if each wire is alternately negative and positive both wires become fluorescent and the length of the fluorescent band indicates the intensity of the current, so that we can compare the relative strength of the closing and breaking currents.

There are several varieties of tube but the diagram illustrates the general type in use.

The instrument is useful. It records the current passing in one direction through the tube. If reverse current is present it represents the difference between the two currents. When both are equal then no reading is recorded. If the reverse is greater than the current in the right direction, then it records on the wrong side of the zero mark. When the oscilloscope tube shows that reverse current is present, then valve tubes must be used to check the reverse. The combination of milliamperemeter, valve, and oscilloscope tubes is a most useful one, helping greatly to regulate the exposures.

The X-ray tube affords an excellent indication of the presence of reverse current. The change in the appearance of the tube which has reverse current passing through it is illustrated in the coloured plate.

Secondary Radiations, Cause, and Methods of Suppression.—

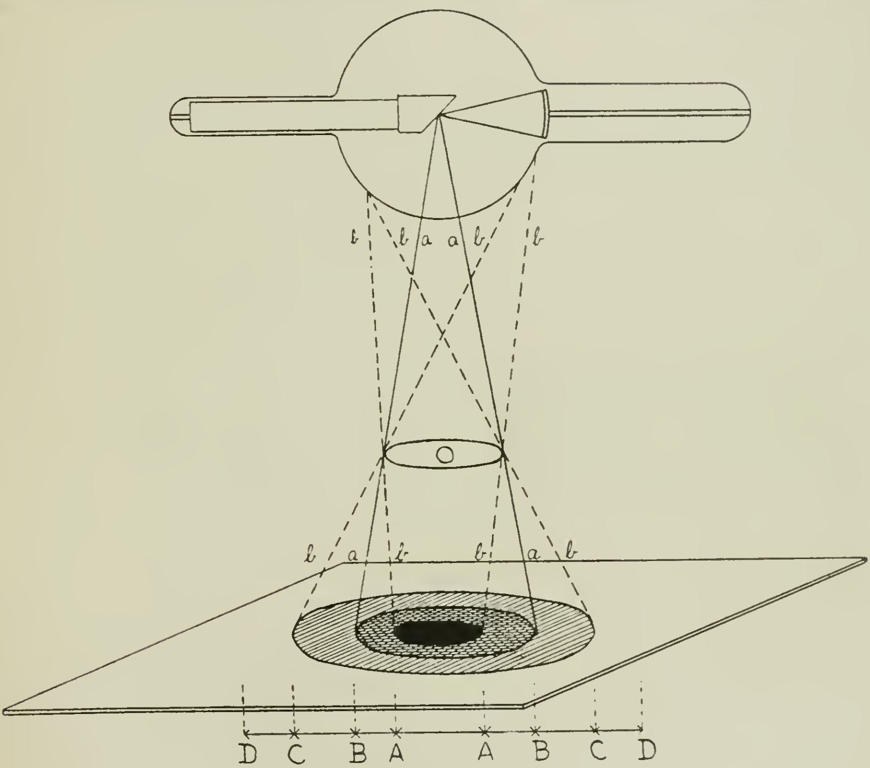


FIG. 76.—Diagrams showing the paths taken by primary beams and secondary rays. (Schall.)

Secondary rays are produced by the reverse current. All those X-rays which do not emanate from the focus of the anti-cathode are called secondary rays. They have the same penetrating power as the primary rays and are plentiful in hard tubes, but they project the outlines of the objects in other directions than the primary rays, and a loss of sharpness results.

When they are present it is necessary to do something to prevent deterioration of the negative. Secondary rays are also produced, or a diffusion of the primary rays takes place in the patient's body. It is probable that both of these manifest themselves during a long exposure. Fig. 76

shows the path taken by the primary beam, and the manner of projection of secondary rays upon the photographic plate.

The X-rays, *a*, *a*, emanating from the focus of the anti-cathode project a shadow, B B, of the object, O, on the plate. If there were no secondary rays this shadow would be of uniform darkness from B to B, and the space, B C D, would be free from any shadow. But if any current discharges in the wrong direction, the so-called secondary rays are generated on the glass of the tube. They are indicated by the dotted lines *b b*. Although weaker in intensity, they project shadows, and in another direction than the primary rays will do ; the shadows overlap, and the part between A B will not be so dark as that between A A and the space between B C will not be as clear as

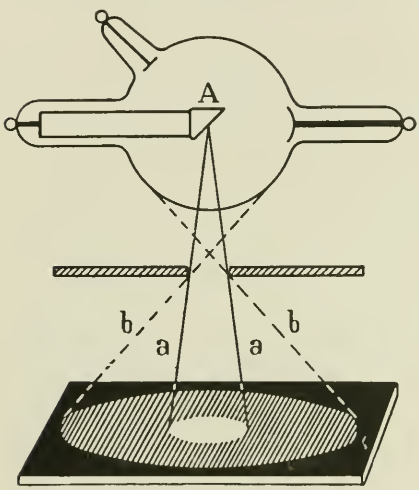


Fig. 77.—Diagram showing the use of a diaphragm between tube and plate. (Schall.)

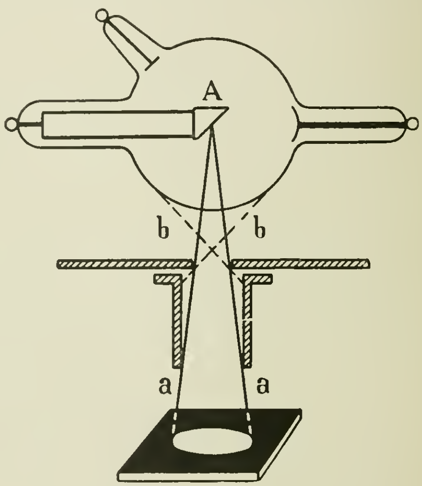


Fig. 78.—Diagram showing the use of a cylinder diaphragm. (Schall.)

that between C D. The effect of the secondary rays is therefore to make the outlines less sharp, and to cause a general fogginess. In consequence of this some details will become indistinct and the finer ones will disappear entirely.

In order to minimise the effect of the secondary rays produced by reverse currents upon the plate, diaphragms are used. A diaphragm alone is not sufficient, and an extension tube should also be combined with the diaphragm.

The above illustration shows this method of checking these ill-effects to some extent.

The illustration (Fig. 77) shows the primary or principal rays *a a* emanating from the anti-cathode A ; the dotted lines *b b* indicate secondary rays emanating from the glass wall of the tube. If we place a diaphragm between tube and plate, some of these secondary rays are stopped, and, the nearer the diaphragm to the tube, and the narrower its aperture, the more efficient will it be. But as metal plates cannot be brought quite close to the tube, some secondary rays will still reach the plate unless a *cylinder diaphragm* is employed. Fig. 78 shows why a cylinder diaphragm is bound to exclude more secondary rays than a flat diaphragm can do; the cylinder diaphragm can also be used with advantage for compression.

Instruments for Estimating the Hardness of the X-Ray Tube.

The X-ray bulb in action presents a picture which in itself is a guide to the condition of the tubes as regards hardness, presence of inverse current, and radiographic value, but if good work is to be maintained it is necessary to be able to record the actual conditions under which a particular standard has been attained. When this has been done it should be possible to reproduce the condition of tube necessary at any time.

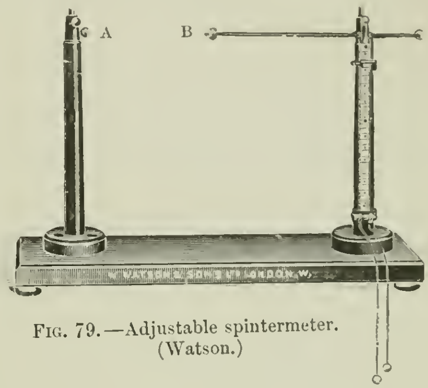


Fig. 79.—Adjustable spintermeter. (Watson.)

There are several methods for estimating the degree of vacuum (or hardness) of the X-ray tube. These are (*a*) measurement of the alternate spark-gap, (*b*) the Bauer Qualimeter, (*c*) radiometers: (1) Walter, (2) Walter-Benoist, (3) Wehnelt crypto-radiometer, (*d*) measurement by the milliamperemeter.

Fig. 80.—Bauer qualimeter. (Favre.)

A rough though practical method of estimating the internal resistance of the X-ray bulb consists of the **Spintermeter,** by means of which the alternate spark-gap is measured.

A convenient form of spintermeter is here shown. The action is simple. The point A is withdrawn to its limit, and the tube set in action. By gradually approximating the point A to the point B a position is reached when the current, instead of passing through the tube sparks between the points A and B, a scale attached giving the distance in inches or centimetres. The spark-gap is measured, and gives approximately the hardness of the X-ray bulb. The spintermeter may be attached to the coil, or more conveniently mounted on a separate base, and placed at some distance from the coil.

The **Bauer Qualimeter** is an instrument for determining the degree of hardness of the X-ray tube. It is useful, but not always to be relied upon.

This instrument is connected by a wire to the negative terminal of the coil or the cathode of the tube. It is a static electrometer and condenser which indicates automatically the potential of the cathode, and hence the quality of the X-rays. The apparatus consists of two wings, which swing between two fixed plates. Both wings and plates are equally charged, so that a repulsion takes place between them. The intensity of this repulsion is in exact proportion to the electrical tension in the secondary circuit, and is indicated by the deviation of a pointer over a suitably divided scale.

As is well known, the penetration of the X-rays is a function of the electrical potential in the secondary circuit, so that a simple measurement of this potential between the anode and cathode will give us an indication of the hardness of the tube. The scale is gauged according to the absorption of the X-rays by sheets of lead of different thickness, increasing regularly from one-tenth of a millimetre to one millimetre.

No. 1 on the scale denotes X-rays of such a hardness as to be totally absorbed by $\frac{1}{10}$ millimetre of lead. When the index is at No. 10 we know that the tube is giving out rays which will penetrate 0·9 millimetre of lead, but will be totally absorbed by 1 millimetre of lead.

As already explained, the instrument is unipolar, being joined up by a single wire to some point in electrical connection with the cathode. The instrument is contained in an ebonite case, which swings freely from a bracket on the wall or a stand, so as to be always in a vertical position.

The following experiment will demonstrate the use of the instrument. The tube is disconnected, and a current from the generator is sent through the spark-gap. In this case the deflection of the qualimeter becomes greater with the increasing spark-gap, while the reading of the milliamperemeter recedes. The spark-gap itself is often used for gauging the hardness of the tube. This proceeding, however, is not exact enough for practical purposes, as the resistance of the spark-gap is dependent upon the form of the electrode ball, point, or disc, and upon the humidity of the atmosphere.

No metallic surface should be allowed to be within a distance of 8 to 10 inches from the instrument. The purposes for which the qualimeter can be used are the following :

Therapeutics.—It is becoming more and more imperative to regulate the hardness of the tubes to the various conditions treated As modern publications almost always give the degree of hardness in qualimeter degrees, it is obviously necessary to employ the qualimeter to obtain the same results. The spark-gap, which has very generally been used up till now, is to be rejected for the reasons mentioned above. In addition to this it is possible, by the help of the qualimeter, to use the so-called indirect calculation of the erythema dose instead of the direct measurement by the Sabouraud pastille, in cases where the degree of hardness employed is always approximately invariable, as is the case in the treatment of the skin and deeper tissues.

The process can be shortly described as follows : Take a new X-ray bulb and give an erythema dose, noting the reading of the milliamperemeter and the qualimeter and the time. The product of these three factors—time, milliamperemeter, and qualimeter degrees—will be always found the same for the erythema dose (under an approximately unvarying degree of hardness), however much the two other factors—intensity and time—may be varied. This method has been scientifically proved by Klingelfuss of Basel. A practical example will serve to illustrate the above. If an erythema dose has been reached in ten minutes with a hardness of 3 Bauer-degrees and an intensity of 4 milliamperes, the product will be $10 \times 3 \times 4 = 120$. If a bulb is being employed which registers 3 degrees of hardness with an intensity of 2 milliamperes, it will take twenty minutes to produce the same result: the product will again be $2 \times 3 \times 20 = 120$. For treatment of the skin and deeper tissues, two different degrees of hardness are generally used (for example, 3 Bauer and 7 Bauer), and the erythema dose need only be calculated once for all. Slight fluctuations in hardness make no difference, and if they occur during exposure they can be adjusted by regulating the primary current. On the other hand, the current employed must be kept within such bounds that the tube remains steady. Should the current through the tube be too strong or too weak, more or less current may be passed through the tube by adjusting the shunt. Too weak a current hardens the tube, whereas too strong a current has the opposite effect.

For comparative scale of the usual instruments for measuring the hardness of tubes, see page 94.

Technique for Exposures.—The time of exposure can be calculated in the same way as that for an erythema dose. We first ascertain within what time and with what degree of hardness and intensity a good negative of any particular region is obtained. These readings may be noted on a chart hung within the protective cabin, and in this way, by using the same figures, a satisfactory result can always be obtained and failures excluded. It is here that the qualimeter is particularly useful, since different degrees of hardness are required for the production of good pictures of various parts of the body. If the operator prefers to use one tube for all purposes, he will find the Bauer air-valve tube most practical. With this he is able to adjust the tube to any degree of hardness desired. For instantaneous exposures the most important point is to adjust the hardness of the tube so that a sufficient number of hard rays may be emitted. To ascertain this, the tube should be driven with a normal intensity of 2 milliamperes, and the hardness tested by the qualimeter. From the resulting negative it can be immediately ascertained whether the tube is too high or too low. If the picture is too faintly shaded, the degree of hardness was too low; if it is too dark, the degree was too high.

As the result of considerable experience in the use of this instrument it may be stated that the qualimeter is particularly suited for radioscopic work, since it indicates the hardness of the tube at a distance, and without the operator being brought into dangerous proximity to the tube in order to measure its hardness.

As has been said, the qualimeter has not only created a possibility of working with greater exactness, but—and to this we again call particular attention—it is not now necessary to come within the dangerous area for the purpose of ascertaining the degree of hardness. Finally, with its help the tubes can be worked much more economically.

Radiometers.—These serve to determine accurately the degree of hardness of the tubes, that is to say, the penetrability of the rays.

Walter's Radiometer consists of a sheet of lead mounted on a wooden frame and with eight circular holes, combined with an adjustable fluorescent

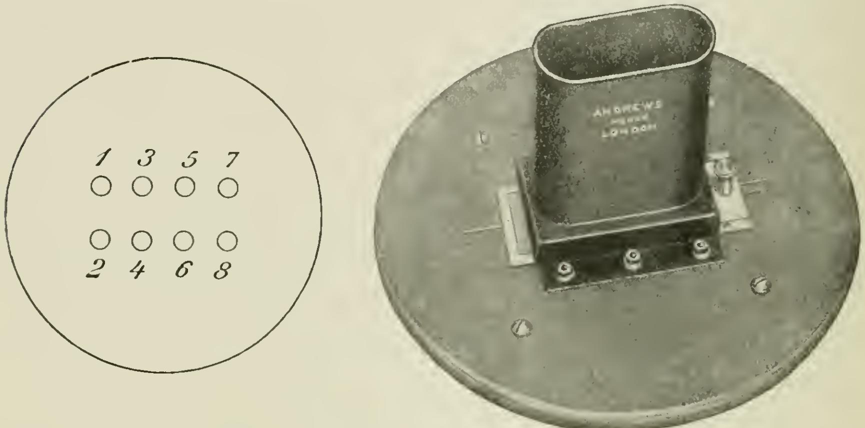


Fig. 81.—Arrangement of holes in Walter's radiometer.

screen. The holes are covered with platinum foil of a thickness varying in geometrical progression from ·005 mm. for hole No. 1 to ·64 mm. for hole No. 8. If the apparatus is placed in the path of the rays a certain number of holes become visible on the fluorescent screen, the number depending on the hardness of the tube. The degree of hardness is indicated by the largest cypher marked on the visible holes.

The *Walter-Benoist Radiometer* has aluminium apertures of various thicknesses and a piece of silver foil. One of the aluminium apertures will

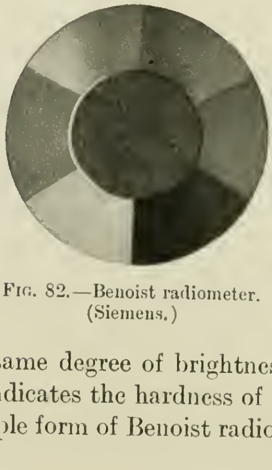


Fig. 82.—Benoist radiometer. (Siemens.)

Fig. 83.—Protected front for Fig. 82.

show the same degree of brightness as the silver foil. The cypher on this aperture indicates the hardness of the tube.

A simple form of Benoist radiometer, with slots for screws, may be fixed on the fluorescent screen ; the lead glass covering the latter protects the operator.

Wehnelt's Crypto-Radiometer is an improvement on the foregoing radiometers. It is provided with a wedge-shaped aluminium strip, and alongside this a flat silver strip, both of which can be moved by means of a ratchet over a brass plate provided with a thin slit. The apparatus is adjusted until both strips show the same degree of brightness on a fluorescent screen. A scale indicates the position of the aluminium strip, *i.e.* the penetration of the tube.

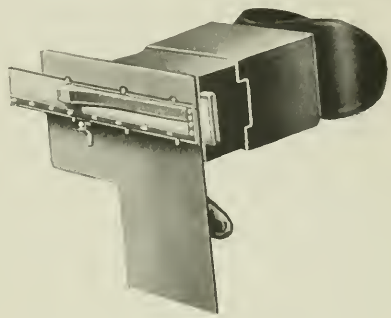


Fig. 84.—Wehnelt's crypto-radiometer. (Siemens.)

This is a useful instrument ; it is efficiently protected, and will be found to be extremely useful for routine work. The radiometer can be fitted behind the lead-lined screen, and a suitable tube-holder attached to the tube while it is being tested. A slit must be cut in the lead linings of the screen. Then the apparatus may be used with safety.

When using these radiometers, and particularly at the present time when heavy currents and hard tubes are coming into general use, it is necessary to point out that the protective devices supplied with the measuring apparatus are not nearly sufficient for the protection of the operator if many observations have to be made daily. The instruments should be mounted on a screen lined with thick lead, and the slots for comparing standards should have thick lead glass.

Fig. 85.—Milliamperemeter. (Siemens.)

The instruments described all estimate more or less accurately the hardness of the X-ray bulb. There are also instruments which measure the quantity of current actually passing to the tube. These are useful in estimating the exposure necessary at particular times. Later, the exact method of combining all the factors required for the estimation of exposure will be described. For our present general purpose it is sufficient to state that there are instruments used to measure the current passing through the tube, the actual quantity of which will vary with the internal resistance of the tube. For example, a soft tube will allow, say, 10 milliamperes to pass, whilst with the same primary current a much harder tube will only allow, say, 1 milliampere to pass.

Measurement of X-Rays by Milliamperemeter.—A milliamperemeter is necessary for this purpose when radiographic exposures are given, and acts by estimating the quantity of current passing through the X-ray tube. That shown is a Deprez-d'Arsonval moving coil instrument, and it is an advantage to have the zero in the centre of the scale for measuring positive and negative currents. They do not show the actual current traversing the X-ray tubes, but its mean value, which can, however, be taken as a relative measure of the intensity of the rays. So long as the pointer remains stationary this indicates that the hardness of the tube is constant. Should the tube, when in use, become harder, the pointer will move towards zero. The instrument is as a rule specially constructed so that it is impossible for sparking to occur inside, and the pointer should be well damped. There are other instruments for measuring the quantity of X-rays used in dosage. These are described more fully in the section on Radio-therapeutics.

The table below gives the comparative values of the instruments most frequently used, namely: Bauer, Wehnelt, Walter, and Benoist.

	soft				medium					hard
Bauer . . .	1	2	3	4	5	6	7	8	9	10
Wehnelt . . .	1·5	3	4·5	6	7·5	9	10·5	12	13·5	15
Walter . . .	1	1-2	2-3	3-4	4-5	5-6	6-7	7-8		
Benoist . . .	1	2	3	4	5	6	7	8	9	10

The ingenious method used for the control of the Coolidge tube appears to be the perfect one for the estimation and control of the hardness of the X-ray given off from the bulb.

The penetrating power of the X-rays is dependent upon the speed of the cathode stream, and the latter is varied by increasing or diminishing the potential at the terminals of the tube. The provision of an ammeter in the battery circuit gives the means necessary for estimating the hardness of the ray. The milliamperemeter in the secondary circuit gives the current passing through the secondary circuit. By using these two indicators together it is possible not only to estimate but to produce at will a particular and fairly constant type of X-ray. This not only dispenses with other more tedious methods of estimation but enables the operator to reproduce at any time the particular ray he may require.

TUBE STANDS, COUCHES, COMPRESSORS, AND SCREENING STANDS

The X-Ray Tube-Stand

There are many varieties and adaptations of this piece of apparatus. The chief essential is that the shield, whatever it may consist of, should be efficiently protective, and of a size capable of holding easily the largest tube. The clamps should have an easy movement, and as little metal as possible should enter into the structure of the shield and tube clamps. This is particularly desirable when heavy currents are used, for otherwise the current may spark from the tube to the metal, and lead to a marked diminution of current passing through the tube and to disappointment in results. The tube is frequently punctured if these precautions are not taken.

There is a type of protected tube-stand which, with some modifications, is made by all the principal manufacturers, and its essential points are enumerated below. Such a stand will answer very well, not only for therapeutic work, but in small installations for radiography and radioscopy. It consists of a wooden tube-box, lined with protective rubber, and as some of these boxes err on the small side, this is a point that should be noted. In place of the wooden tube-box an X-ray-proof lead glass bowl may be used. This should, however, be completely enclosed by having at the back of the tube a lead rubber cap. To the front of this box all diaphragms, applicators, and pastille-holders can be fitted. This box is attached to a horizontal wooden arm by a mechanical method, and this part should be carefully examined in regard to easy working and complete mechanical details to avoid subsequent disappointment and annoyance. As the tube-box may have to carry considerable weight and still be used at all angles and positions, each movement should be controlled by a separate solid metal clamp, and not by one that can wear or compress. It is better to pay a little more for extra work in this direction than to court disaster by some part not holding well, and perhaps allowing the tube-box to drop in the middle of an exposure. The horizontal arm has a rack-and-pinion adjustment, which is fitted by means of a bracket, with a vertical rack-and-pinion movement attached to a wooden upright, which in turn should be mounted on a solid metal base, not a wooden one, so as to make a stable and fairly rigid apparatus. All adjustments can then be conveniently made. An elaboration of this is the pillar tube-stand, suitable for use with much larger outfits and for all kinds of work.

Description and Use of Pillar Stands.—The pillar stand consists of a solid pedestal with castors, which carries a vertical column of steel tube. An adjustable sleeve, to which one end of a wire is secured, is mounted on this column. The wire runs over a pulley, and carries a movable lead weight inside the steel tube, which serves to balance the tube-box and the whole movable system. The sleeve can be locked in any position by the lever. The pulley is secured to a ball-bearing, and can revolve freely round the top of the column. The sleeve has a horizontal arm, which carries a second sleeve. In order to avoid a displacement of the sleeve in the longitudinal direction of the arm, the latter has a groove at the end, which engages the screw of the lever. The tube-box is hinged to the sleeve in such a manner that it may be revolved horizontally through an angle of about 90°. In order to fix the position of the angle, there is a circular slot above the hinge, through which travels the screw of the lever. If, now, the lever is turned to the right, its head is firmly pressed against the slot, and thereby prevents any further rotation of the hinge. The sleeve, together with the tube-box, can be turned radially to the arm. The sleeve is locked by tightening up a screw by means of the lever, so that the sleeve is pressed on to the arm. Thus, the tube-box can be moved as follows: (*a*) up and down; (*b*) round the column; (*c*) round the arm; (*d*) through an angle of 90° round any axis vertical to the arm, so that this pillar stand permits of adjusting the position of the tube within the widest limits.

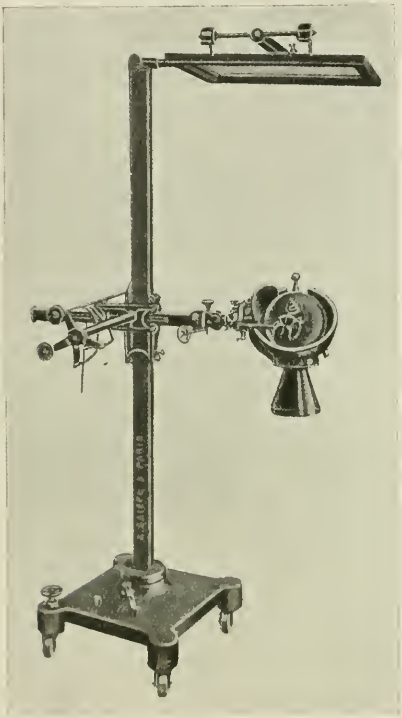


FIG. 86.—Pillar stand, protected tube-box and accessories. (A. Gaiffe.)

The tube-box itself is lined inside with lead rubber material, as a protection against accidental effects of the rays. Its back forms a door. The front is provided with a rectangular opening of about 170 × 220 mm., in which the accessories subsequently to be described are inserted. In order to be able conveniently to manipulate the tube-box during adjustment, it is provided with a handle. One of the sides is fitted with an observation window of lead glass, through which the X-rays can only penetrate with difficulty, and this may be closed by the shutter, when making a fluoroscopic examination. Two pieces of wood with slots are fitted to the under side of the box, between which the tube-holder, together with the tube, is inserted. The holder must be secured to the cathode neck of the tube.

The latter must be so mounted that the anti-cathode is turned towards the front of the box (with the opening for the X-rays), and occupies about the

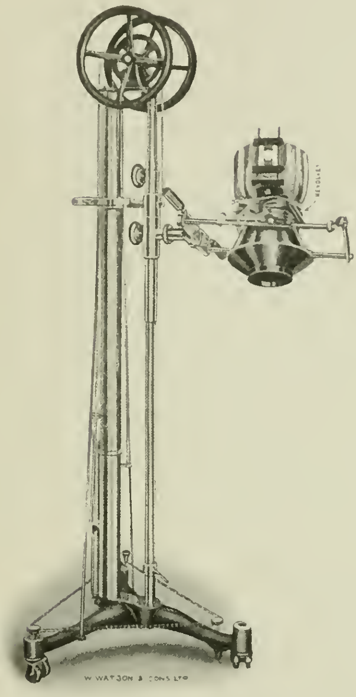


Fig. 87.—A form of tube-stand, which combines many useful mechanical movements. (Watson.)

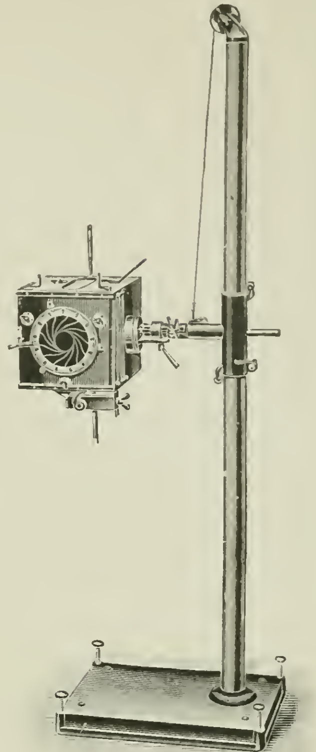


Fig. 88.—A convenient type of tube-stand with iris diaphragm.

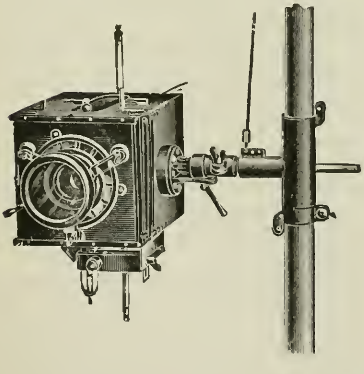


Fig. 89.—Tube-box with extension tube.

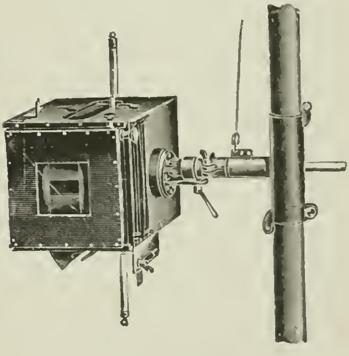


Fig. 90.—Tube-box with rectangular diaphragm.

centre of the box. The tube-holder can be fixed by turning the wood screw to the right.

In order that neither the operator nor the patient may receive shocks due to sparks jumping from the tube to any part of the stand, a terminal is mounted on the pedestal, which is connected with all the metal parts of the stand, and also with the accessories, which are inserted in the front opening of the box through the metal strip which runs along the tube-box. This terminal must be connected to a water-pipe by means of an insulated or bare wire, or to an earthed conductor, should this be available on the supply mains.

In order to prevent any accidental movement of the stand, two screws are provided in the pedestal by means of which the latter may be slightly raised, so as to put two castors out of gear.

Accessories.—The following accessories are generally supplied with these tubes. 1. A wooden *Carrier* with an opening (about 170 × 170 mm.), which is inserted in the front of the tube-box, and fixed by means of the screw. In order to centre the X-rays, it may be adjusted up and down to the extent of about 30 mm. The accessories, compressor diaphragm, iris diaphragm, and holders, can be attached to this carrier.

2. A *Compressor Diaphragm*, about 140 mm. long by 125 mm. diameter, aids in the production of radiographs showing good contrast, this being attained primarily by screening the rays not required, and partly by efficiently fixing or compressing the patient.

3. An *Iris Diaphragm*. The largest diameter of the opening is about 105 mm. and the smallest about 25 mm.

4. A *Holder*, which must be inserted in the wood carrier, and is intended for holding the three diaphragms as well as the centering device. A *Holder* for the lead glass tubes, or applicators, which must also be inserted in the wood carrier. The tubes can be fixed by turning a wooden screw.

5. Four *Lead Glass Tubes*, of 100 mm. length, with diameters of about 18, 40, 50, and 75 mm. respectively. The largest tube is conical, and should be inserted into the carrier at its widest end.

6. A *Centering Device*, which consists of a small metal tube attached to a circular plate, to the free end of which a small circular screen of barium platino-cyanide is attached. The centering device must be inserted in the holder. In order to centre the tube, the latter is switched on, and the wood carrier with the centering device is moved until the small fluorescent screen is in a state of complete fluorescence, that is, until it shows a complete circle and not only a part of the circle. Centering can also be well effected without the tube being switched on, by removing the cap and the little screen from the centering tube, and observing the anti-cathode through the latter, and then adjusting the tube until the centre of the anti-cathode is observed.

7. A *Shutter Diaphragm*, the aperture of which can be variably adjusted by means of levers, in the form of a rectangle. The largest aperture is 120 × 120 mm.

8. *Holders for the Tubes.*—In order to avoid the unnecessary removal of the tube-holder from the tube, when another tube is employed, extra

tube-holders are recommended, so that with this arrangement the tubes are always centered when they have once been adjusted.

9. A *Pastille Holder.*—This can be inserted in an opening in the base of the box, and is provided with a circular slot, in which the re-agents of the Saboraud and Noiré radiometers are inserted. By turning the metal piece the re-agents are prevented from falling out.

Instructions for Use.—The stand is earthed, as already described, by connecting the terminal by means of a wire with gas or water pipe, or possibly with the neutral wire of the supply mains. When moving the tube-box, the handle can always be held with one hand. In order to adjust the box, it should be brought to the desired position by loosening the lever, and then fixed rigidly at once by means of the same lever. This lever when loosened should only be turned so far as to enable the box to be easily revolved. Then the box can be turned into the desired position round the arm, and fixed again by means of a lever. Finally, the box is raised to the desired height, and if necessary rotated round the column, and then tightened up again by means of the lever provided. Care should always be taken that the fixing screw for the tube-carrier is well tightened up, so that the wood carrier does not fall out when turning the box. Should it be desired to apply fluoroscopy or radiography to thick parts of the body, the wood carrier front may be completely removed.

Couches and Stands

Essentials of the X-Ray Examination Couch.—The essential points about such a couch are :

(1) Conveniences for the adjustment of patient, tube, and plate.

(2) Safety for patient and operator against the dangers of over-exposure to X-rays.

So far as the patient is concerned these points can be obtained by : (*a*) Limitation of the time of exposure ; (*b*) distance of the tube from the skin surface ; (*c*) the interposition between the patient's skin and the active tube of a light aluminium filter.

The operator should take all known methods of protection : (*a*) Careful shutting in of the tube by tested X-ray-proof material ; (*b*) the use of gloves and aprons, or the interposition of a lead-lined X-ray-proof screen between the body and the tube ; (*c*) the protection of the fluorescent screen by lead glass ; (*d*) the minimum time for each exposure.

It is necessary to remember that, in spite of all precautions, if screening is employed daily over a long period of time no protective measures can be considered absolutely safe.

A **simple couch** will suffice for a small installation. In large institutions, where a considerable amount of work has to be got through quickly, a couch with mechanical contrivances is necessary. The couch should be sufficiently protected, and should have conveniences for working with the tube below the table. When possible overhead work should be undertaken.

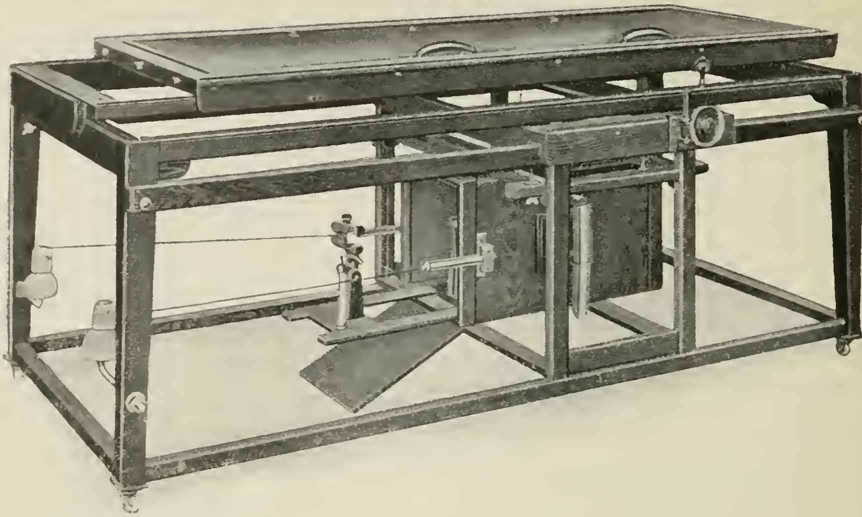


Fig. 91.—A convenient form of X-ray couch. (Siemens.)

Fitted with a protected tube-box, the top of the table is so constructed that the patient may be moved in several directions to facilitate centering of parts of the body over the X-ray tube.

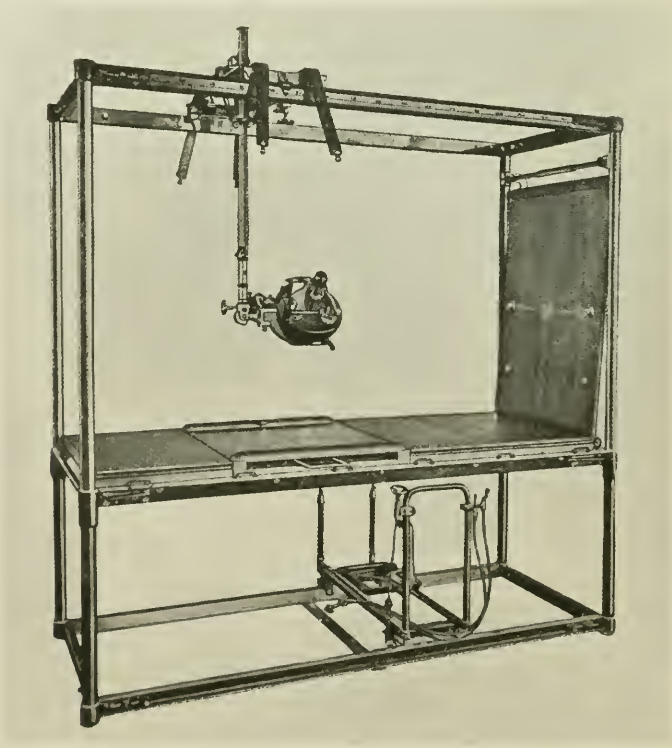


Fig. 92.—The Belot X-ray couch. (A. Gaiffe.)

Arranged for work with the tube either over or under the couch. The mechanical construction and working of this couch leaves nothing to be desired, combining, as it does, rigidity of structure with very easy and reliable movement.

More elaborate couches are manufactured by such well-known firms as Gaiffe of Paris and the Victor Company and others in America. These are most complete and easy of manipulation.

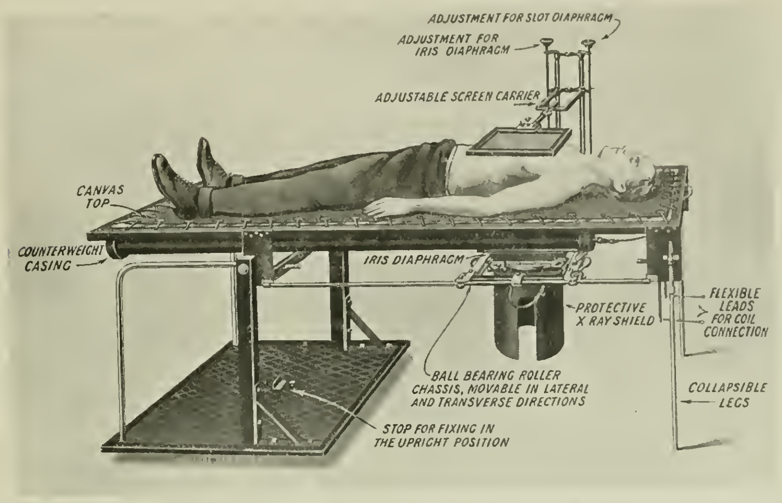


FIG. 93.—Grevillite combined screening stand and X-ray couch. (Medical Supply Association.)

Combined X-Ray Couch and Upright Screening Stand.—There are conditions under which it is not always possible, either from lack of space or other circumstances, to have the X-ray couch and a separate screening stand; then an apparatus similar to the accompanying figures will be found useful.

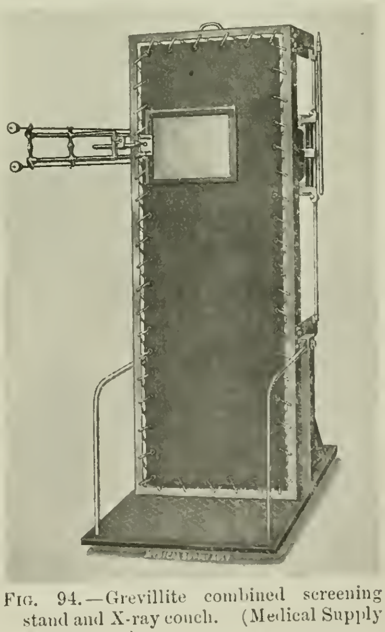


FIG. 94.—Grevillite combined screening stand and X-ray couch. (Medical Supply Association.)

The Victor Company have made a combined couch for examination in the prone or upright position. It is also capable of *tilting* with the patient on it, and the tube moves with the couch; the latter movement is a most useful one for the examination of the alimentary tract in patients who have taken an opaque meal.

Cavendish Universal X-Ray Couch.—This couch has several unique features, and is a useful couch for localisation and general X-ray work. It is made of solid oak, and is perfectly rigid.

The top is of 3-ply wood, mounted on a strong frame of oak hinged to the oak frame of the couch itself, thus permitting of easy inspection of the focus tube-box, diaphragms, and operating mechanism, etc.

The *Focus Tube-Box* is of oak, lined throughout with lead rubber material of 2·6 mm. thickness and 4·8 density, while the top is also covered with sheet lead. In addition a lead rubber apron is fitted on each side of the tube-box. The protective arrangements comply with the requirements which have been experimentally worked out by several authorities; most of the recent couches have been constructed to meet these requirements.

The tube-box is underslung, travelling longitudinally on fibre wheels

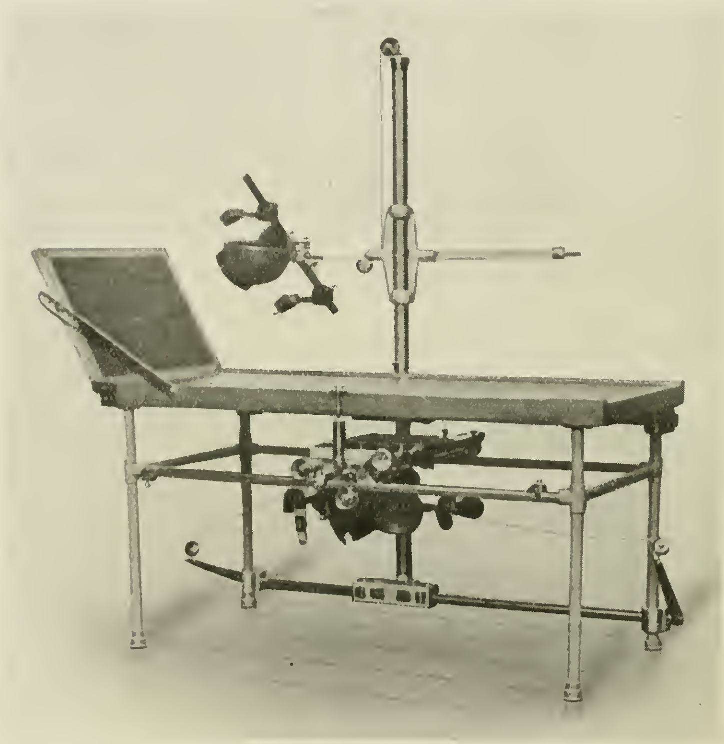


Fig. 95.—Belot new couch. (Medical Supply Association.)
This smaller couch is admirably adapted for localisation of foreign bodies, and for radiography above or below the couch. It embodies all the mechanical excellences of the larger Belot couch.

along steel rails running the whole length of the couch. A hand-brake is provided for holding the carriage rigid in any desired position.

The ends of the tube-box are hinged to drop down. The two clamps which support the focus tube are mounted on a frame removable from the box and allowing of easy centering by means of an external handle and small inspection window of lead glass.

An adjustable rectangular diaphragm, protected by lead on its upper surface, is fitted to the tube-box, while in addition a simple cylinder diaphragm is provided to screen off secondary radiations.

The *Controls* are mounted on the front of the carriage. These comprise a handle for the transverse movement and two handles for operating the two pairs of shutters of rectangular diaphragm, all working with the greatest ease, but free from play.

A *Localising Arm*, carrying plumb line and bob, is attached to the main pillar and is raised or lowered by means of a rack and pinion over a centimetre scale, thus indicating the exact height of the plumb bob, and therefore of the plate, from the anti-cathode of the focus tube. The main upright is also arranged to carry an adjustable plate-holder which is brought exactly central beneath the plumb bob. This plate-holder is fitted with cross wires, and with frames to take all sizes of plates.

A centimetre scale, with pointer, is fitted to the side of the tube-box,

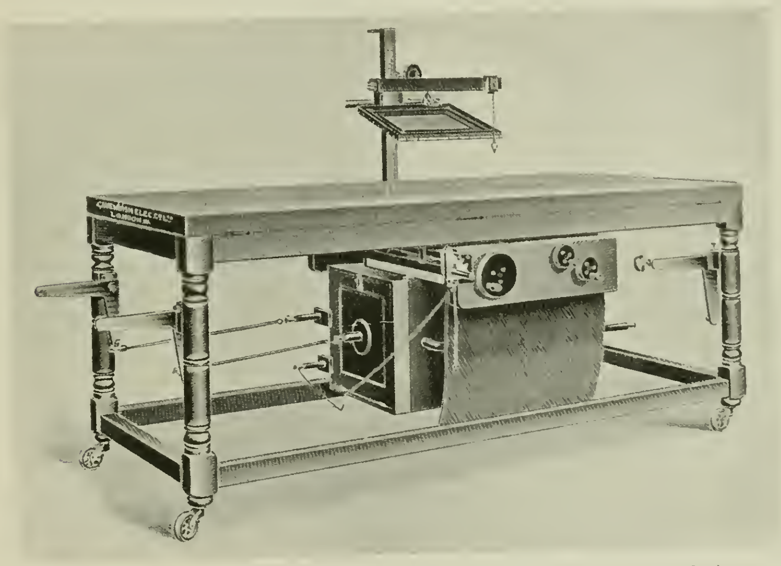


FIG. 96.—Cavendish universal X-ray couch. (Cavendish Electrical Co.)

corresponding with a scale on the horizontal arm, so that the exact position of the tube beneath the couch can be instantly determined.

The *Main Pillar* and arm can be swung round quite clear of the couch top when desired, or may be totally removed, while the horizontal arm itself is hinged so as to swing up vertically when the plate-holder is in use or when placing a patient in position, etc.

The new couch embodies a number of distinct improvements that all tend to increase the general efficiency of operation and combine convenience and facility with accuracy and precision.

On the Use of the Diaphragm Compressor

This compressor is a most important piece of apparatus, mounted upon a suitable table with adjustments and tube-carriers, and is a great help to the radiographer, since it facilitates the work and saves time if the adjustments are easily worked. There are many forms to select from, and a great deal must be left to the individual worker. Nearly all are modelled on the *Albers-Schönberg*, and such a compressor apparatus has become an essential auxiliary for high-class radiography of particular regions. The chief advantages which are guaranteed to the radiographer by its proper use may be briefly summarised as follows :

1. By means of the compressor diaphragm the secondary rays which affect the value of the radiograph can be screened completely.

2. The parts under examination can be kept absolutely at rest, so that

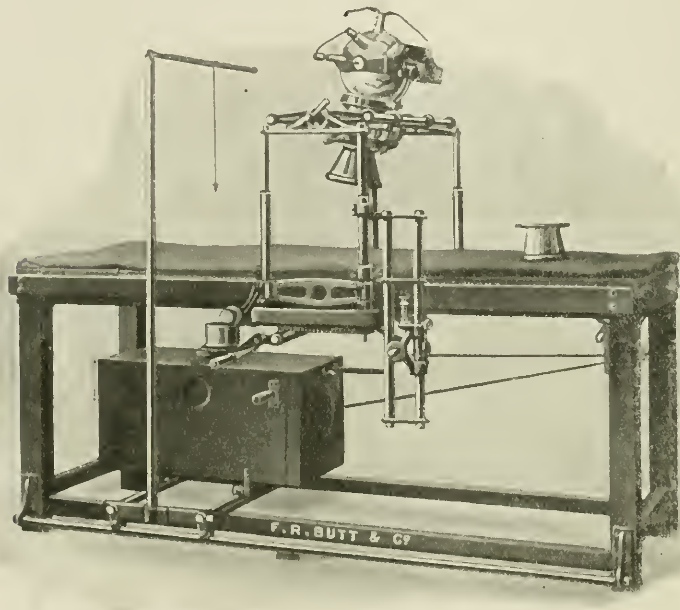


Fig. 97.—A couch fitted with protected tube-box underneath. (Butt.)

This has movements in three directions, and is arranged for stereoscopic work. An upright attached to the box carries a horizontal arm to which is fitted a plumb-line to indicate the exact position of the anti-cathode of the tube. On the upper aspect of the couch a movable tube-holder is fitted. This has attached to it a compression diaphragm.

want of sharpness, due to voluntary or involuntary movement, to respiration or pulsation of the heart, is eliminated.

3. All parts of the human body can be radiographed, so that the compressor apparatus can be employed for all exposures required, with the exception of general exposures over a large area of the body.

It is now generally recognised that a certain quantity of X-rays are given off by the glass walls as well as by the other metal electrodes of the tube, in addition to the bulk of the X-rays emanating from the anti-cathode. Owing to the presence of inverse current in the tube, some cathode rays are produced from the anode, and others also start from the edges of the cathode, and these are all converted into secondary X-rays.

These secondary X-rays, which are produced in much larger quantities in hard than in soft tubes, are the primary cause of lack of definition, detail, and contrast; they produce general fog in negatives, and so lessen the value of the results of the more difficult radiographs.

The compressor apparatus consists of a lead-lined metal cylindrical or rectangular box, with an opening at the upper end for the insertion of diaphragms. The cylinder effectually absorbs and screens off all stray secondary rays, allowing only those X-rays emanating from the anti-cathode to reach the photographic plate. This can be proved at any time by observing a fluorescent screen placed below the cylinder, when a brightly illuminated centre only will be seen; a wider circle of fluorescence, indicating the presence of stray secondary rays, is only observed when inefficient diaphragms are employed.

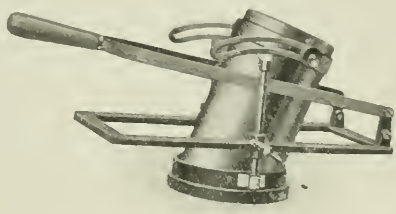


Fig. 98.—Extension tube of a kidney compressor to show method of compression. (Siemens.)

By the time the X-rays have traversed the distance between the tube and the fluorescent screen or photographic plate, they have become very much diffused, and the thicker the subject the greater the diffusion. The primary object, therefore, is to reduce this distance in order to obtain quicker exposure and sharper and more brilliant radiographs, and for this purpose it is necessary to combine a compressor with the cylinder. The end of the cylinder is fitted with an ebonite rim, and the whole apparatus is raised and lowered by a lever.

Some parts of the human body can be compressed three or four inches without causing any discomfort to the patient, and the time of exposure is thus very greatly reduced. The compressor is also of great use in reducing the movement due to respiration, and thereby conduces to greater sharpness and definition in the radiograph.

There are modifications of this type of compressor which are preferred by some workers, and possess advantages over the Albers-Schönberg. The compressor introduced by Dr. Gilbert Scott possesses all the advantages of the Schönberg apparatus, and is much more adaptable and easy of manipulation.

The Upright Screening Stand.—This useful piece of apparatus may be simple or very complicated, with conveniences for stereoscopic exposures. All movements must be easy. Several types of screening stands are illustrated. The most useful are Wenckebach, the extremely ingenious but complicated one shown in Fig. 105, and the apparatus of Butt with automatic stereoscopic movements (see Fig. 99, p. 106). Care should be taken to ensure the complete protection of the operator. The fluorescent screen should have protected handles, and the front must be protected by thick lead glass. This should be tested to make sure that it is efficient.

The Screening Stand may be constructed in such a manner that it can be used for other purposes in addition to screening, and so it forms a very complete type of apparatus, particularly in small hospitals where the space devoted to the X-ray department is very limited. The apparatus consists essentially of a large, totally enclosed protective lined tube-box, with lead-glass observation window fitted with sliding shutter on one side; at the back is a door and on the front are fitted the diaphragm, compressor tube,

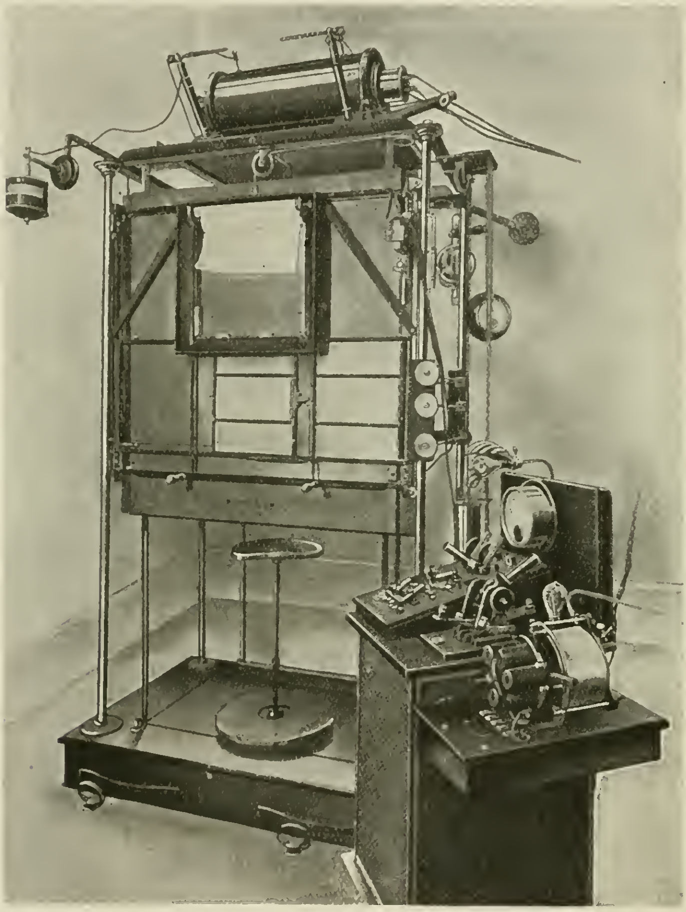


FIG. 99.—Screening stand arranged for stereoscopic work in the upright position. (Butt.) The apparatus is arranged so that tube- and plate-holder move automatically at the right moment. The whole mechanism is controlled from the switch table.

and other pieces of apparatus. This tube-box is mounted on a carrying frame, which is fitted with slots, so that it can be brought nearer or taken further from the patient, also the whole box can be entirely rotated. The frame carrying the tube-box is attached to a strong square framework, running up and down between the upright sides of the stand. This frame is fitted with counterweights, so as to move freely up and down, and on the front of it are two rods projecting forward, and sliding on these rods is a metal carrier and carriage for holding the fluorescent screen or plate-holder, which can be angled to follow the contour of any part it is desired to examine or radiograph. The whole of the control of this apparatus can be manipulated from the front, so that it is entirely unnecessary for the operator to put his hands near the tube-box. As will be seen, the fluorescent screen can be moved freely across the patient by means of its own protective handles; the aperture of the diaphragm is controlled by means of the two flexible cables and handles seen on the right in Fig. 100; the handle on the left-hand side causes the tube-box to travel from side to side at the back, and the large wheel seen on the right is for raising and lowering the whole of the frame carrying the tube-box and screen-carrier. Now, as to its other purposes, the tube-box can be lowered to the ground and rotated, a quarter-revolution bringing the opening of the tube-box towards the ceiling of the room. A couch or table can be moved over the box in this position, and examinations and radiographs made with the tube below. Or, on the other hand, the tube-box can be rotated from its screening position a quarter-turn in the other direction, so that the aperture is towards the floor. The frame carrying the tube-box can be now raised upwards, a compressor tube affixed to the front of the box, and a couch or table passed under or

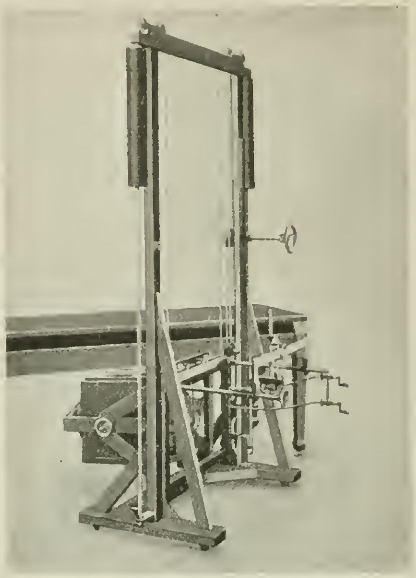


Fig. 100.—Screening stand arranged for work beneath the table. (Siemens.)

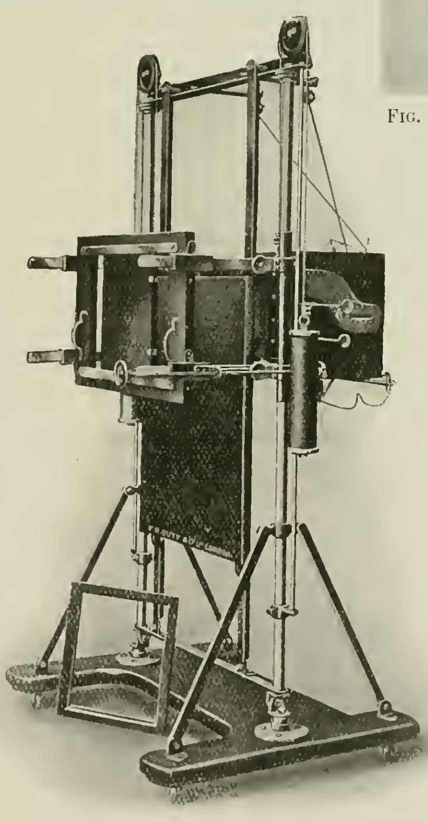


Fig. 101.—Screening stand arranged for examinations in the upright position. (Butt & Co.)

through the stand. The tube-box can now be lowered, and compression work undertaken as with an Albers-Schönberg compressor. If the tube-box be rotated a half-revolution, then the patient can be brought close up to the diaphragm, and on the other hand tele-radiographs can be accurately made with the aid of a simple centering arrangement provided with the apparatus.

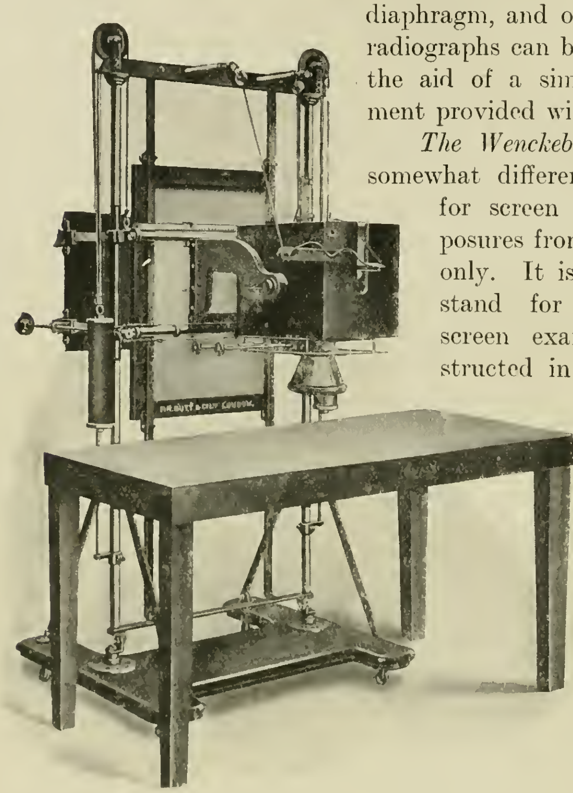


Fig. 102.—Screening stand arranged to work as a compressor. (Butt & Co.)

The Wenckebach Screening Stand is somewhat different, and is constructed for screen examinations and exposures from the screening position only. It is, however, an excellent stand for those specialising in screen examinations. It is constructed in two units. One unit might be called the screen unit and the other the tube-box unit. The former consists of a frame carrying the fluorescent screen and plate-holder, which fits into a parchment frame marked with divisions, so that a note can be made of the exact position, and an examination repeated. This frame and screen is counterbalanced, and can be easily raised or lowered in a large upright framework. On the back of this framework are fitted at convenient intervals bands for passing round the patient to keep him in a fixed position. There is also a lamp which throws a light on the scales of the second part of the apparatus. The latter or second part consists of a large protective-lined tube-box, mounted on a frame which is carried on a second upright framework, and from this project forward, one on either side, two long arms with convenient wheel handles, one on the left-hand side for raising and lowering the tube-box, and one on the right for moving it across from side to side ; also close beside the latter are the two flexible cables and handles for controlling the aperture of the diaphragm. This second part is mounted on rails laid in the floor, and the object of the long arms is that the operator, while making his screen examination, can push the tube further away, or draw it nearer the patient with the utmost comfort and ease. A stool can also be provided to support the patient if necessary.

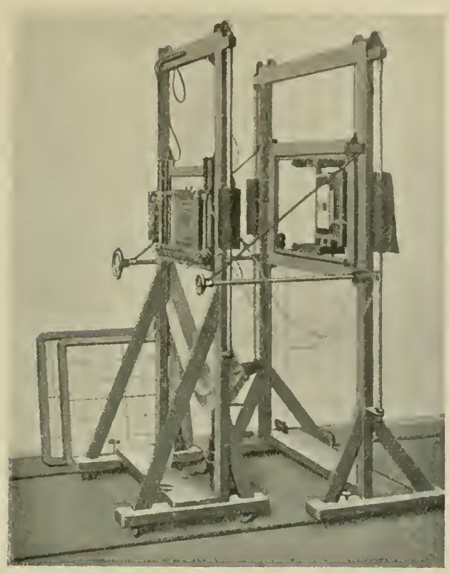


FIG. 103.—Wenckebach screening stand. (Siemens.)

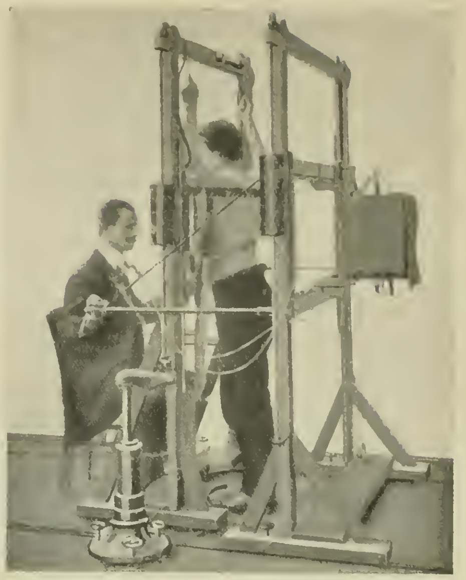


FIG. 104.—Wenckebach screening stand. (Siemens.)

Universal Safety and Protective Tube-stand.—The demand for a universal apparatus is increasing as the real importance of the Röntgen examination of the internal organs is recognised. There are, of course, various devices for radiographing the patient in a standing or sitting position, but a simple and handy universal apparatus for both fluoroscopy and radiography is much to be desired. The desiderata of such an apparatus are many. The most important of these are the fixation of the body, the straightness of the trunk, and the accurate adjustment of the normal ray to any desired point on the surface. In addition, any such apparatus, if it is to be universal, must be equally efficient when the patient is reclining, sitting, or standing, and should be easily adjustable for teleradiography up to a distance of 2 metres or more. Finally, it should be capable of being easily and quickly handled, and it should not be too expensive.

First, as to the straightness of the trunk. It is absolutely essential that this should be as accurate as possible for exact radiography, and for localisation and measurement of the internal organs. Straightening by the eye is quite inadequate. The difficulty may be overcome satisfactorily by a mechanical device which carries out this straightening automatically. The trunk is often moved during the exposure, even by intelligent patients, and the picture thereby spoilt. This difficulty is partially overcome by instantaneous exposures of one-hundredth of a second or less; but, nevertheless, an efficient means of holding the patient is absolutely necessary since no movement should take place between the completion of the adjustment of the part to be radiographed and the exposure of the negative. Moreover, it is of importance to minimise to a certain extent the costal and abdominal respiratory movements, especially in radiography of the kidneys.

The apparatus shown in Fig. 105 is constructed from this point of view. It consists of a heavy base and framework, with a well-protected tube-box, which can be moved in all directions, the fluorescent screen being suspended by cords and counterpoises. There is in addition a special tube adjustment, and a set of rails and a small table for distance radiography.

The fixation board, which will take a plate-holder of any size, is furnished with three pairs of padded clamps, each pair being moved by the simple turning of a single handle, so that they are always at the same distance from the middle line of the board. The upper pair are made in the form of well-padded shoulder-caps, inclined in such a manner that, when brought together, they hold the patient's shoulders firmly, and at the same time press them against the plate-holder. To the top edge of the board is attached an adjustable support for the chin. Between the two lower pairs of clamps is a broad compression band, which can be readily tightened up by turning a handle. Another handle can raise or depress the plate-holder, so that even after the fixation of the trunk the plate may be brought to any required height, or depressed as much as 20 centimetres below the board, for radiography of the pelvic region.

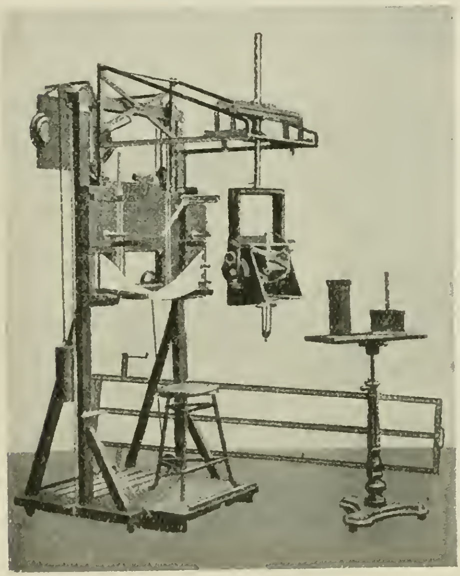


Fig. 105.—A useful form of universal examining stand. (Siemens.)

This combines nearly all the movements that are necessary for a complete examination, and is efficiently protected.

In the centre of the supporting board is a large opening for the diaphragm tube, for use in radioscopy. There is also a receptacle for small cross-shaped lead labels, backed with plaster, which can easily be attached to any portion of the skin.

For radiography in a reclining position the fixation board may be detached from the framework. As it weighs only 40 pounds, it can easily be carried by one person, and placed on the X-ray table or ambulance.

The framework is 6 feet high, and is mounted on castors. It is provided with a small wooden frame with counterpoises, which is easily adjustable by means of a hand-wheel at the back. This carries the fixation board and clamps, and the guide rails for the tube-box and fluorescent screen.

A Rotating Plate-changing Stand in Modern Radiographic Work

A simple method for the rapid changing of plates is often required. It is often necessary to take a number of plates in quick succession, and the advantage of doing so will be readily appreciated by any one who has to examine stomach conditions by means of the opaque meal. The ordinary methods employed do not allow of a sufficiently rapid change of plate to enable us to study the peristaltic wave of the stomach ; particularly is it necessary closely to observe the behaviour of the pyloric end of the stomach and the duodenum. The screen examination is extremely useful, and gives the observer all the information he seeks, but when he attempts to obtain the same effects on a plate, or a series of plates, then he finds the need for a more accurate mechanical arrangement than most of the plate-changers in use. Gregory Cole has solved the problem in radiography of the stomach in the prone position. Howard Pirie has recently described another form of table for the prone position. For the upright position we have not been so fortunate. Rosenthal and Rieder have used for several years a most complicated apparatus for the production of a pseudo-cinematographic effect by taking a number of plates, about six to a second. Dessauer has still more recently introduced a plate-changer, designed to give a cinematographic effect, on much the same principle as Rieder and Rosenthal. In both the principle of the falling plate has been adopted. Both also suffer from the same disadvantages, extreme expensiveness, coupled with a doubtful efficiency in practical work. Some time ago the subject was discussed with Mr. Caulfeild, and he designed and put together the apparatus described below. This combines extreme simplicity of design with a remarkable efficiency in execution, a combination somewhat infrequently met with in X-ray apparatus.

The following details of construction will enable any intelligent carpenter to make the apparatus. At the usual speed of operation six plates can be exposed in 12 seconds. The stand can be used for two or more plates, and the intervals between each exposure can be varied in several ways. The apparatus can be worked by hand instead of automatically, when the intervals between the exposures may be as long as we desire, or by alternating the cassette or plates with dummies the intervals of time between exposures may be as follows :

6 exposures in	2	seconds interval.	12	seconds in all.	
3	,,	4	,,	,,	12 ,, ,,
2	,,	6	,,	,,	12 ,, ,,

In stomach work these combinations will be found useful, as it is only necessary to examine the movements of the organ on the screen to determine what interval is necessary to get a complete cycle on the six plates. The plate-changer can also be utilised for stereoscopic work, when the plates automatically change position, while in the interval the tube may be displaced by hand or automatically, whichever is the more convenient method. The apparatus in its present form is only of value when very rapid exposures can be made. It works very well with a single flash apparatus or with a transformer which is capable of giving good plates with exposures of about one twenty-fifth of a second. With exposures beyond this limit the pictures are apt to be blurred by the vibration of the plate, a condition which is unavoidable in this type of apparatus.

Details of Apparatus.—A triangular frame A carries a bracket B, on one end of which is mounted the ball-bearing C, and at the other end a block carrying the sliding plunger D.

The circular table E rotates on the ball-bearing C, and is provided with a framework which holds the six cassettes F, which are arranged vertically round the edge of the table. A leaden weight H is placed in the centre of the table over the bearing. The table is rotated by a cord R and weight (not shown); the cord runs in groove R. Beneath the table are six stops G, which butt against the plunger D, and so check the movement of the table when any plate is in position for exposure.

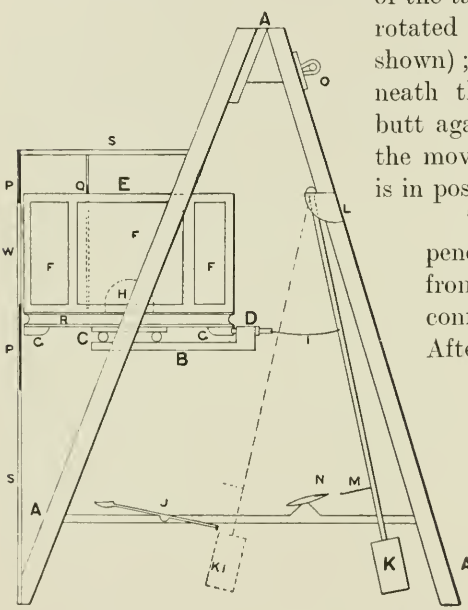


Fig. 106.—A rotating plate-changing device. Side elevation.

The plunger D is withdrawn by the pendulum K, one metre long, swinging from the bracket L. A short chain I connects the pendulum to the plunger. After withdrawal the plunger is returned by a spring (not shown). A lever J has a hook on its end, which holds back the pendulum when in position K1.

A spring M is attached to the pendulum rod, and a cigar-shaped piece N is fixed in such a position that the spring M, during the opposite swings of the pendulum, passes alternately above and below the piece N. At the end of N, and on its upper surface only, is a metal contact. N and M are electrically connected with the pilot lamp O, so that this lamp glows when the pendulum, moving from K1 to K, pulls M across the upper side of N. When the pendulum moves from K to K1, M passes on the under side of N and no contact is made.

A frame S carries a thin wood panel PWP, against which the patient leans. The lead lining P P has a window W exactly opposite the plate to be exposed. A sheet of lead Q hangs down inside the revolving cassettes, but not touching them. Lead wings T are provided, as shown in Fig. 107. The combination of the lead sheets, P Q and T, stops any rays reaching any plate except that one which is facing the window at the time of exposure.

It was originally intended that the tube X should be fired by the contacts M N, but it was found that these soon burned up with the heavy currents necessary for quick exposures. The contacts are now connected to the pilot lamp O, which indicates to the assistant in charge, looking through the window of the protected cabin U, when to pull over the spring switch of the single flash apparatus. The pendulum completes its double swing in two seconds, which gives time for the assistant to manipulate the switch, and for the table to bring a fresh plate into position. The single flash assures the sharpness of the negatives. With relatively slow exposures of one-tenth of a second the effects of vibration were visible on the plate. This form of apparatus does not appear suitable for exposures at a quicker rate than one plate in two seconds. A new type of apparatus is now being considered, with which it is hoped to expose up to eight plates in one second. Any rate

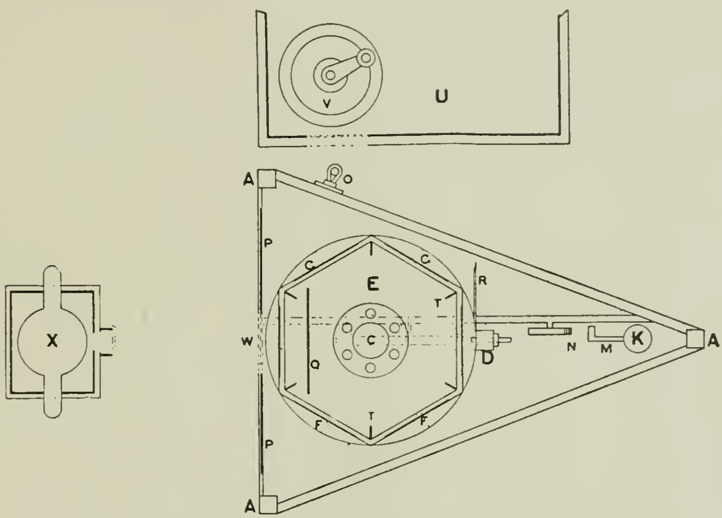


FIG. 107.—Diagram to illustrate method of using the rotating plate changing device.

slower than one plate in two seconds can be got with the present form by working the plunger D by hand independently of the pendulum.

The apparatus is wound up by rotating the table by hand. The pendulum is hooked back into position K1. The patient is adjusted against W. The foot lever J is depressed. The pendulum moves from K1 towards K. The spring M passes over N, and the contacts M N light the pilot lamp. The assistant in U pulls over the single flash lever V, exposing the first plate. The spring M leaves the contact N, the pilot lamp goes out. The further movement of the pendulum towards K tightens the chain I and withdraws the plunger D. The table begins to turn under the pull of cord R and weight. Pendulum now returns from K towards K1. The chain I slacks and a spring (not shown) pushes back the plunger D. The revolution of the table brings one of the stops G against the plunger and the table stops with the next plate in position for exposure. The pendulum spring M now passes underneath the piece N. No contact is made. The pendulum is now at K1 position of its swing, and the cycle is repeated. The double swing of the pendulum takes two seconds. The contact N is set so as to light the pilot lamp about one-third of a second before the plunger is withdrawn. It is found that the single flash switch can be worked in this time. About one second elapses between withdrawing the plunger and the next stop coming against the returned plunger, so that about two-thirds of a second are available to partially damp out the vibrations caused by the sudden checking of the table. With single flash exposures no vibration is visible on the plate.

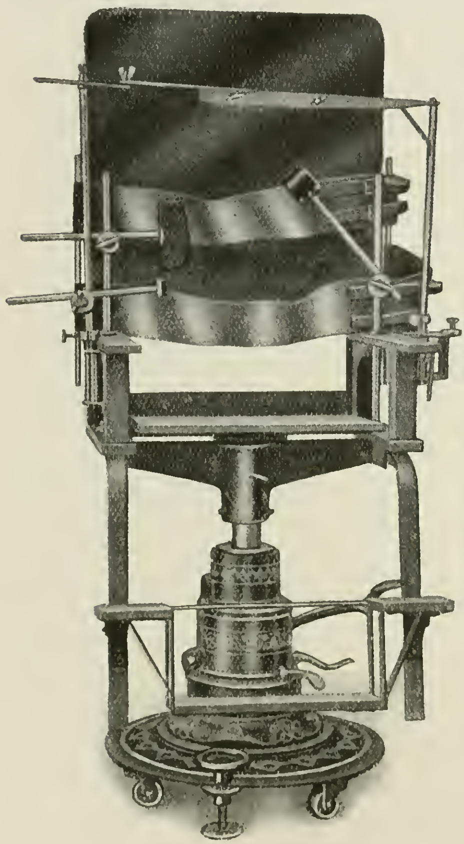


Fig. 108.—Examining chair fitted with mechanical movements to facilitate the rapid manipulation of the patient. (Siemens.)

Universal Examining Chair.—This chair is used on the Continent chiefly for screen work and for superficial radiographs. The chief object in view in the design of the chair is to obtain as exact and as reliable a fixed position for the patient as possible. This is obtained by two wide straps fixed to the sail-cloth back of the chair, which hold the patient in an upright position, and by two easily adjustable axle supports, which prevent any movement sideways. The feet are well supported by a footstool, which may be adjusted to any height. When taking screen observations of the stomach, the seat can be replaced by a bicycle saddle, which is better suited for this work.

In order that the observer can undertake the examination of these parts in the most comfortable position, and without bending, it is necessary, after fixing the patient, to bring him to the height desired by the observer. This is attained by an oil pump which is built into the very massive base of the chair, and which is operated by pressure of the foot on a pedal. The locking of the chair takes place automatically after the foot is removed.

The fluorescent screen necessary for observation is secured by a holder fixed to the arms of the chair, and may be adjusted in all directions. In addition, the screen can be removed very easily, so that it may be replaced quickly by a dark slide containing the photographic plate.

Should it be desired, after the examination has been completed, to bring the patient back into the original position, it is only necessary to depress the second small pedal in order to release the locking device. Thereupon, the chair sinks slowly into the original position, owing to the excellent braking power of the pump.

The chair can be moved about easily, and may also be turned round its vertical axis with the foot, so that the hands of the radiographer need never come in the path of the rays.

Rieder's Exposure Stand.—Another very useful piece of apparatus is an exposure stand, originally used by Dr. Rieder for taking radiographs, with the patient either sitting or standing. It is specially suitable for thorax, stomach, and abdomen exposures.

Another valuable addition is a little protective **lead-lined screen,** with an adjustable lead-lined sliding leaf, arranged with a clamp for fluorescent screen and plate-holder. This little apparatus should be mounted on good castors so as to move freely, and it can be used for many purposes. It is constructed primarily for the protection of the operator when screening, but it can also be used for the patient to stand against, and to support himself whilst being radiographed. It can be used in conjunction with any X-ray couch, screening-stand, or tube-stand, and also if a long therapeutic application has to be made this screen can be placed between the operator and the tube, so that no radiation from the latter falls on the operator.

Grid Diaphragm.—For very thick subjects it is sometimes an advantage to use a grid diaphragm between the screen and the patient. The diaphragm is constructed of thin strips well covered with lead, which absorb most of the secondary radiations given off when hard rays penetrate the body of the patient. These secondary rays are diffused, and they therefore blur the sharp picture produced by the primary ray. Since these strips are arranged in the direction of the primary rays it is necessary to keep constant the distance between the tube and the screen. This distance should be 60 cms. Experiments have demonstrated that a definite ratio must be observed between the length and height of the various cells; these have therefore been constructed in squares with a side length of 2 cms. and a depth of 5 cms. The grid is mounted on a strong frame, which is provided with means for attaching it to the fluorescent screen.

THE ARRANGEMENT OF APPARATUS

In a work of this size it is difficult to deal adequately with so wide a subject, but for practical purposes it will be sufficient to describe :

(1) A small installation.

(2) An installation for a general hospital or consulting radiologist.

(3) An installation for a special hospital.

(4) Installations for military service.

Each scheme will be capable of modifications according to local demands, but the basis of each should form a working nucleus upon which the individual operator may build a complete scheme. A scheme for the arrangement of apparatus and a system of dealing with photographic details will also be included. A system of filing negatives and reports should be adopted in every department.

1. A Small Installation

There is a demand for small installations to meet the needs of practitioners desirous of examining their cases in the course of ordinary consultation, of school clinics, especially those where treatment is carried out, and where occasional radioscopic examination is required, and finally of small hospitals, where for various reasons an elaborate installation is not possible.

A comparatively large coil (say 15-inch spark-gap) is desirable. Further, a simple control apparatus is required, either mounted on the wall or preferably on a wheeled trolley ; and a mercury interrupter, with dielectric of paraffin or preferably of gas ; when rapid exposures are desired, an electrolytic interrupter should be added, and this necessitates a change-over switch in the control apparatus. In order to suppress reverse current, an adjustable spark-gap, introduced in the secondary circuit, is sufficient where small currents are used ; while for heavier discharges, obtained by using the electrolytic interrupter, valve tubes are necessary. A suitable tube-holder, with efficient protection and with the necessary fittings for therapeutic work, is required, viz. tripod for treatment of ringworm, pastille holder, filters, etc. A simple examination-table with three-ply wood or canvas top, and a simple screening-stand are requisite. A vellum window may be fitted into a wooden frame which can be moved to any portion of the couch. This allows practically all the rays to pass through to the fluorescent screen, and gives the maximum value in screening. These may be combined in an apparatus which may be used for either purpose. A fluorescent screen, protected with lead glass and provided with hand-guards, a supply of X-ray tubes, X-ray-proof gloves, Benoist radiometer, oscilloscope tube, milliamperemeter, and photographic plates are also necessary. When instantaneous exposures are to be carried out, a cassette for plates with an intensifying screen must be added.

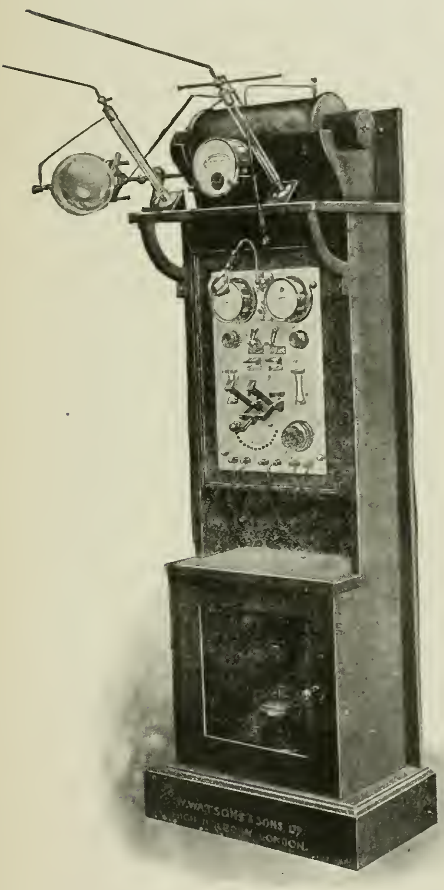


FIG. 109.—A convenient form of apparatus arranged on an upright cabinet. (Watson.)

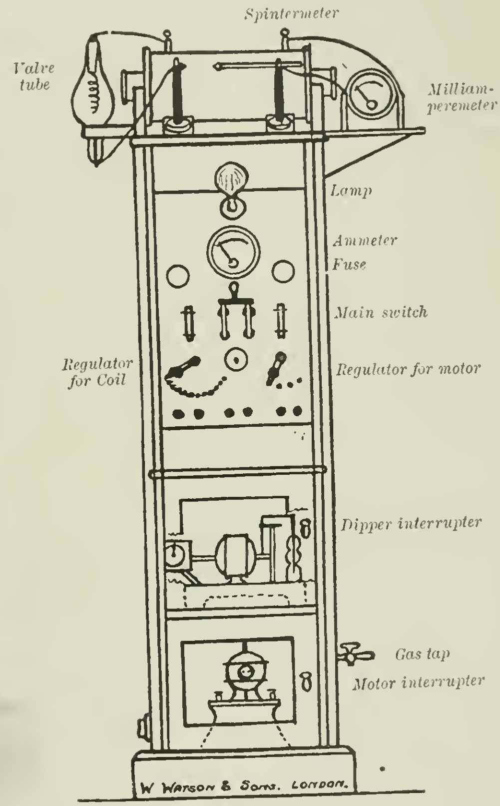


FIG. 110.—To illustrate the parts as arranged in Fig. 109.

Portable Apparatus.—This may take the form of a trolley outfit in a compact cabinet, capable of being wheeled from ward to ward, and obtaining its current supply from the electric mains. For work in private houses or institutions unprovided with electrical installation, it is necessary to have an outfit which derives its current supply from accumulators. (If an interrupter with a gas dielectric is used, a supply of gas must be provided for; this may be carried in a rubber bag.) Essentially it is the same as the small installation described above, but a 12-inch coil is for various reasons more convenient. A mercury-interrupter of the Cavendish type is convenient; a tube-stand of lighter construction and a portable examination table may be added. The connections of the accumulators are illustrated in Fig. 3, page 13. When exposing plates with a portable apparatus, a cassette and intensifying screen should be used, as this greatly shortens the length of exposure.

Exigencies of space or monetary considerations may occasionally give rise to the question of combining one apparatus in such a way that it may be used for work in a hospital or consulting-room and be portable for work at small hospitals or private homes. What, then, is the best combination of the essential and accessory apparatus?

It is possible to have a motor-car specially constructed to carry a dynamo, which will supply the low-tension current for the apparatus when used for both purposes, or a dynamo may be fixed at home and another of the same capacity fixed on the car. The apparatus can then be used under the same conditions of primary current. The coil and accessories are so fitted that they can be readily carried about. A 16-inch coil is most useful. The interrupter should also be rendered portable, and all the connections can be arranged for rapid adjustments. A combined couch and screening stand can be constructed which is readily taken to pieces for transport. An outfit arranged on these lines can quite readily be constructed which will do first-class work at any place. The improvement in the output of work done away from the department will be very marked.

2. Installation for a General Hospital or Consulting Radiologist

The essential features of a somewhat more complex installation may be briefly enumerated.

(*a*) One or more coil outfits, with, where possible, a powerful instrument, such as a high-tension rectifier, a Snook machine, or a powerful coil outfit fitted with three breaks (mercury with gas dielectric, triple Wehnelt, and, if possible, a single-impulse switch). With a high-tension rectifier apparatus one can add a single-impulse switch.

(*b*) A second outfit of less capacity is useful as a stand-by in case of a break-down. This is an important point, because in a large institution work must go on constantly.

(*c*) Overhead high-tension cables, properly insulated, should be stretched from one end of the room to the other.

(*d*) A change-over switch is useful when two installations are used, and another switch for quickly connecting to various pieces of apparatus. This may also be accompanied by adjustable tube leads, running on wheels along the high-tension cables. The plan shown on page 119 illustrates the best arrangement of apparatus when one room only is available. The various pieces of apparatus are marked on the plan.

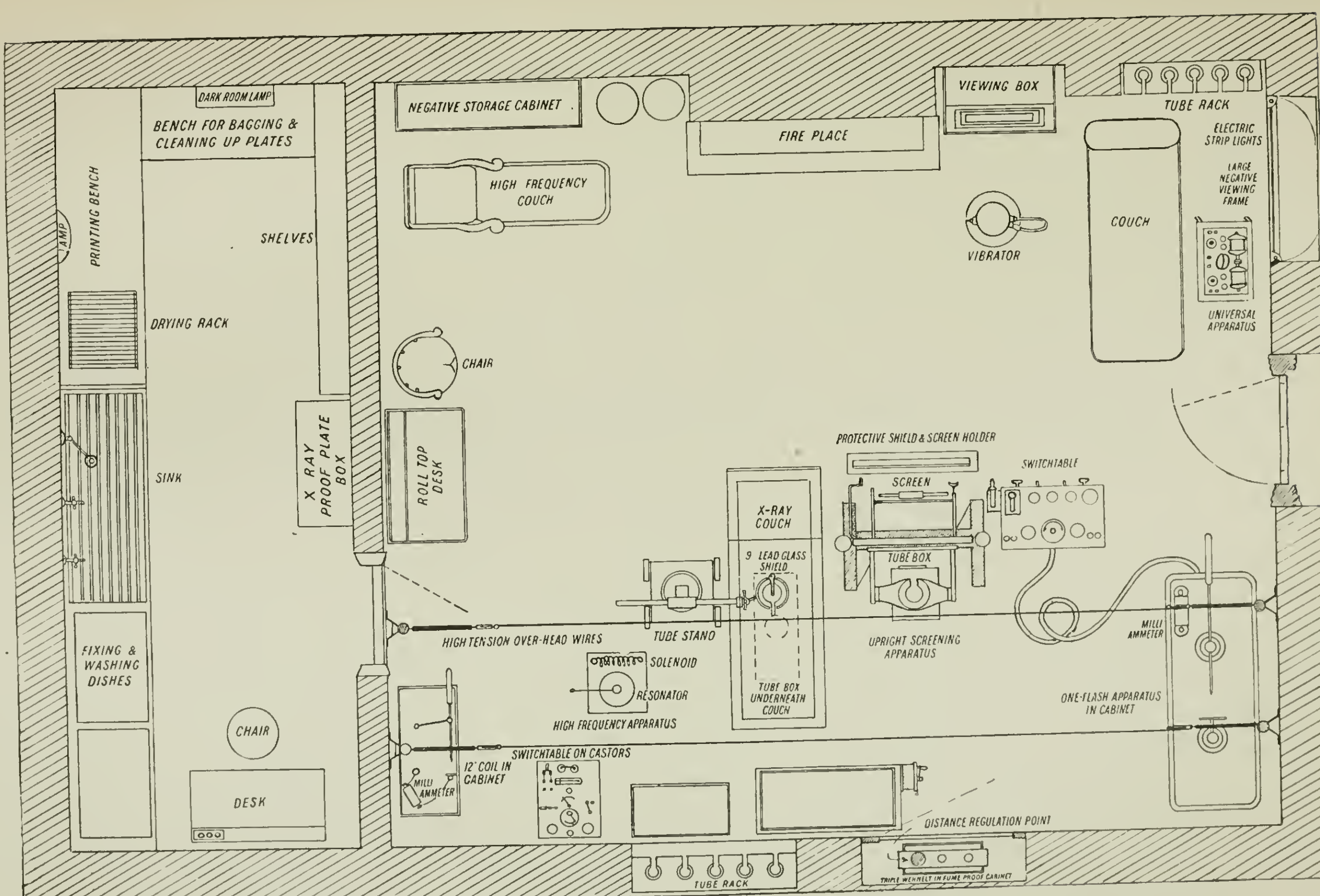


Fig. 111.—Plan for consulting-room or hospital outfit, showing method of arranging apparatus in order to facilitate rapid working. The equipment is arranged for radiographic and therapeutic work, and includes accessory apparatus, high frequency, galvanism and faradism, vibrator, etc.

The dark room should be in close proximity to the X-ray room, but care should be taken to ensure thorough protection of the unexposed plates and papers.

For large institutions a suite of rooms is necessary. When a separate building is available, it can be specially planned to meet the requirements of the institution.

Should it be necessary to plan an X-ray department, great care should be paid to the arrangements of the radiographic room. The lighting of this room should be carefully planned. A large window means that trouble will arise when it is necessary to darken the room, consequently the smallest possible window space must be allowed. The radiographic room must be large. It should have in close proximity to it a waiting-room, one or more dressing-rooms, and a preparation-rcom where patients may be anæsthetised or an opaque enema administered prior to taking the patient to the radiographic room. This room should have an adequate supply of hot and cold water and other conveniences. These additional rooms should open into the radiographic room. Doorways should be wide enough to allow of the passage of a large trolley.

3. Installation for a Special Hospital

The plan of an Electrical Institution is shown on page 121 ; this building was specially planned for the purpose, and is quite complete in details. The ground floor contains a waiting-hall with lavatory accommodation, a small consulting-room with dressing-rooms,—the former fitted with a desk, filing cabinet, and examination lamps, etc.

The Radiographic Room.—This contains the large single-impulse apparatus, with the regulating apparatus in a lead-lined protection cabinet. A couch and screening-stand form the chief accessory apparatus. Cupboards for tubes, etc., form part of the furniture of the room. There is a viewing-box, to take two 15 by 12 negatives, a stereoscope, and a large viewing-box, to take six 15 by 12 plates, each with removable fronts, adapted to hold smaller plates. Two dark rooms adjoin the radiographic room. The inner dark room is also fitted with viewing apparatus.

The First Floor.—This is devoted to radio- and electro-therapy, and has, in addition to the special X-ray treatment cubicles, cubicles for carbon-dioxide snow work, radium treatment, diathermy, the mercury vapour lamp, Schnee four-celled bath, and galvanism and faradism.

A feature of this floor is a small room fitted as a combined X-ray department and an operating theatre for diathermy, electro-coagulation, and for the removal of foreign bodies.

The Dark Room.—When a large amount of work has to be got through it is necessary to have a large and well-equipped dark room, with possibly an outer dark room. This should contain cupboards for plates, papers, etc. A reducing lantern is useful for the supply of reduced prints, lantern slides, etc. The dark room should be carefully planned to facilitate speedy working. The entrance should be carefully guarded by two doors with an interval between. It is an advantage to have them so arranged that the two cannot

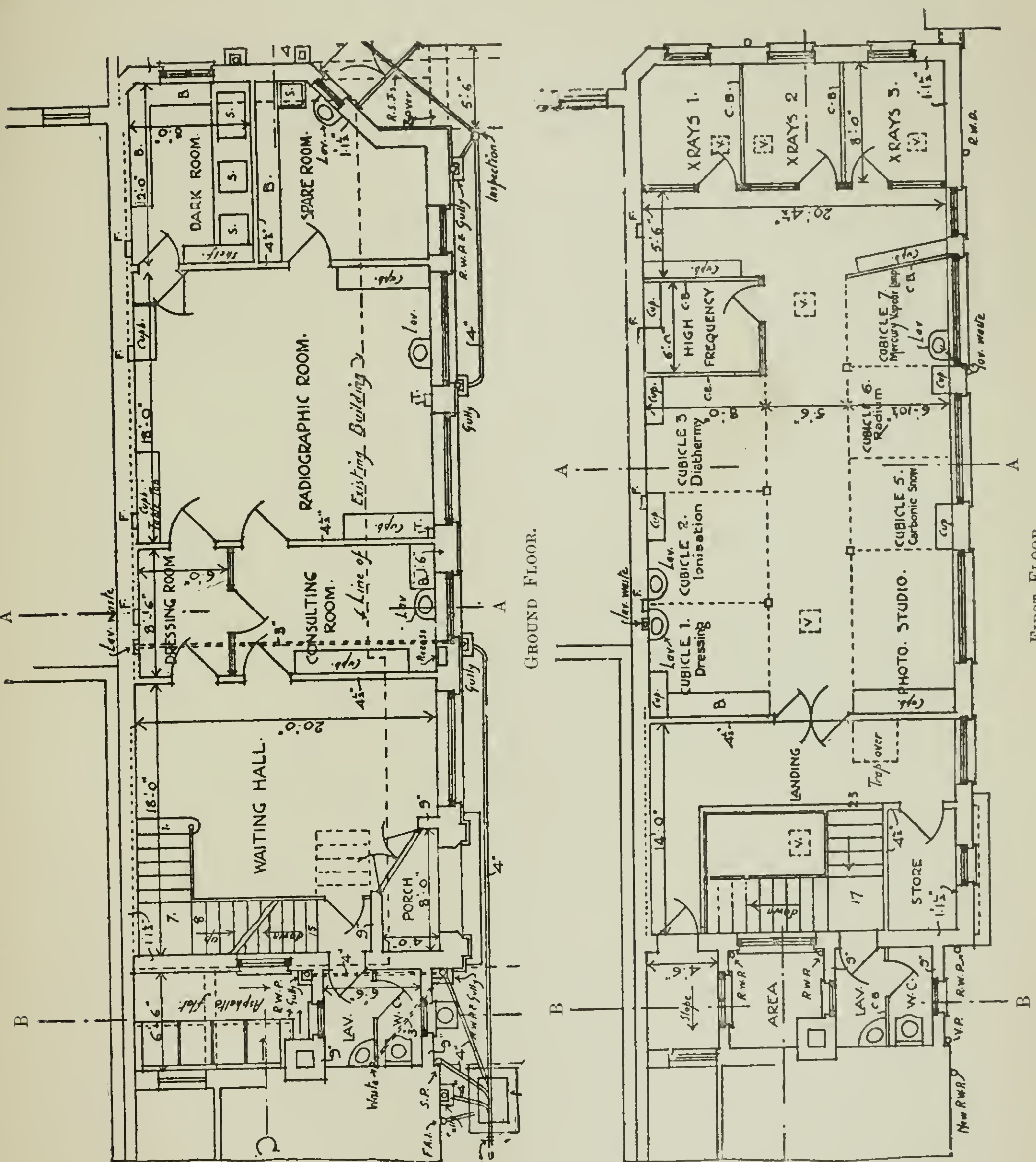


FIG. 112.—Plans of the electrical department at the Cancer Hospital, Fulham. (By kind permission of E. M. Pole, Esq.)

be open at the same time. Shelving and cupboard accommodation should be provided. The ventilation should be good, and the heating of the room should be carefully attended to. Several lights are required: (*a*) Two or more ruby lights; (*b*) a yellow light for printing, etc. The development should be arranged for at one end of the room, a capacious sink with a good supply of hot and cold water being provided. Next to this is placed a washing tank, then a fixing tank or tanks, and lastly another washing tank. These should all be large and deep. A drying rack should be placed near to the final washing tank, also a viewing-box for inspection of the negatives. Plates and papers should be kept in a lead-lined cupboard if an outer dark room has not been provided.

In the largest hospitals the organisation of the electrical department becomes more involved. It is only when the whole department is under efficient control that good work can be turned out in a routine manner. The efficiency, therefore, of such departments depends on thorough organisation more than on individual effort. All the workers must be trained to perform their particular part of the general whole in the most efficient manner possible.

4. Installations for Military Service

Radiography has been found to be of great use in the detection of fractures and foreign bodies. Its value therefore in the medical equipment of the military service is beyond doubt. Thorough equipment and organisation are necessary to obtain the maximum value, as it is often a matter of great difficulty to deal in the most efficient manner with the large amount of work which at times presents itself. The ideal scheme is one which is simple, comprehensive, and efficient, and this entails much preliminary detail work. An efficient scheme, and one which commends itself, consists of: (*a*) An installation at a base hospital, (*b*) a serviceable installation at a collecting hospital, (*c*) a portable outfit for use on the field.

(*a*) **The Equipment at the Base Hospital** should be complete in every detail, because it is here that very important work must be thoroughly and expeditiously carried out.

The question of staff depends on the amount of work required, but the equipment suitable for a general hospital is suitable for such a base hospital. The advantages of a thorough equipment are other than purely radiographic, as it can be used as a training school where medical men, nurses, and orderlies can receive appropriate instruction in all branches of the work. Also it is here that cases requiring very careful investigation and exact localisation can be referred from the collecting centre.

The equipment for a large base hospital, which at the present time may accommodate several thousands of patients, is a matter of considerable importance when rapid output of work is so essential. There are several important considerations which should be carefully provided for. Ample room must be provided for a number of people to work at the same time; the important question of air space and floor space should be thoroughly gone into; X-ray operators should not be asked to work in small, badly-ventilated rooms. The maximum space should be allowed, and there must be an efficient system of ventilation provided.

The chief radiographic room should be at least 30 feet by 25 feet, and the minimum height from floor to ceiling should be at least 15 feet.

Wherever possible it is well to have several installations in separate rooms which should intercommunicate. One room should be equipped for screen examinations, and be also capable of being used for radiography; an X-ray couch and upright screening-stand should therefore be provided in each room.

There should be ample accommodation for waiting patients, and as many of the cases come down on stretchers the space should be sufficient to accommodate a number of cases. Dressing-rooms or cubicles should be provided for each examination-room. The photographic dark rooms should be commodious, and should have all facilities for rapid work.

In military work, provision should be made for an operating theatre with a complete X-ray installation fitted with localising devices. This theatre should be complete in every respect so that any operation may be conducted with efficiency and safety. When such a theatre is built for the combined purposes of surgery and radiography there are many practical details which can be here indicated, though in each case the special requirements of the operators will naturally modify these.

The chief essentials are air space, light, and the ability to exclude the light when required. Air space is easily provided. The lighting of the theatre for operative purposes should be artificial. For thorough darkening of the room no system is better than the provision of light-tight shutters; the ventilating shafts must be light-proof. It is a good plan to use a ruby or yellow light as much as possible, even to the extent of operating by it; this will greatly aid the surgeon in his appreciation of the position of a foreign body when the X-rays are in use.

The X-ray apparatus may be installed in an adjoining room, the high-tension leads being carried into the operating-room through tunnels in the floor; it is only necessary to have in the operating room a simple control table for the use of the X-ray operator.

The X-ray table should be specially constructed so that it combines the utility of a good operating table with a radiographic couch. There are several of these already in use, the most useful being the Ironside Bruce Director Couch. This particular apparatus has several defects, but these can readily be rectified. A useful arrangement of apparatus would be to have the X-ray tube-box fixed and to have the table readily movable to any position above it. This would allow of rapid adjustment of the part to be operated upon over the X-ray tube.

Whichever system is used it should be made possible to rapidly localise the foreign body immediately before operation; and when necessary it should be possible quickly to turn on the X-rays, screen the patient, and so aid the surgeon in his operation.

The X-ray department would be incomplete if no provision were made for the storage of X-ray negatives. A large room should be provided with a convenient system of racks, and an indexing cabinet for the keeping of records of cases.

Experience has taught us that far too little attention is paid by designers to this most important matter; nothing will aid the rapid output of work more than the provision of ample room for these records.

In the working of a large radiographic department, detail in all directions, when thoroughly attended to, ensures success, and much detail work cannot be carried out if provision is not made for it.

Sufficient time must be allowed for each case to be carefully attended to; though it is quite possible to examine and report on an individual case in an hour or less, it must be understood that except in very urgent cases it is undesirable to " rush " a department in this way. It is better to allow the routine work to go on than to suspend it while an urgent case is under examination. In a very large hospital it would be preferable to put aside an installation and attendants for " urgent cases," thus avoiding delays with patients already arranged for and waiting. Routine work cannot be interrupted without in some way impairing its efficiency.

X-Ray Mobile Outfit.—The problem of the satisfactory execution of a large amount of X-ray work in connection with large armies operating over a changing field is one of great difficulty. The arrangements of the base hospital can satisfactorily be carried out; the equipment of nearly all hospitals behind the fighting line is also fairly well provided for—each has its X-ray department, which is more or less sufficient to provide for the requirements. It appears to be an economical measure to have a mobile unit which in itself embodies the complete installation of a fairly large hospital, and is at the same time easily moved from place to place; it is capable of doing the X-ray work of a number of small hospitals which, if equipped separately, could not possibly be so efficient as the mobile unit. A powerful motor-car should be able to get over a considerable mileage daily, and in the course of an hour or two at each hospital satisfactorily perform the X-ray work. In this way it is also possible to economise in staff, for two competent men attached to the unit should be able to do all the work at the smaller hospitals,—where without such an outfit possibly six or more men would be employed.

The following description is given of a mobile unit of sufficient power to do high-class work. This is provided with a tent, but, as is explained in the description, the latter is not the most satisfactory arrangement.

An outfit similar to that described would be very useful also in large towns where there are a number of private hospitals which have no X-ray outfit, or if they are provided with such it is generally not sufficiently powerful to carry out the heavy work so often required in localising bullets, fractures, and the examination of the stomach and intestines by the aid of the opaque meal. The mobile outfit described may be rendered still more mobile if the X-ray apparatus is fitted in such a manner that it can readily be detached and carried into a hospital or home; it could

A

B

F. Butt & Co.

PLATE V.—X-RAY MOBILE OUTFIT.

A. Complete outfit with tent erected and front side removed to show arrangement of apparatus.
B. Nearer view of interior of tent, showing apparatus ready for use.

then satisfactorily execute the work of a dozen or more of these small homes. The low-tension current is carried from the dynamo of the waggon along insulated cables to the place where the apparatus is being used.

The X-ray couch should then be a combined one, offering facilities for operations as well as localising. A useful table is illustrated in Fig. 113. This is made to the design of Major M'Kechnie for use in a portable operating

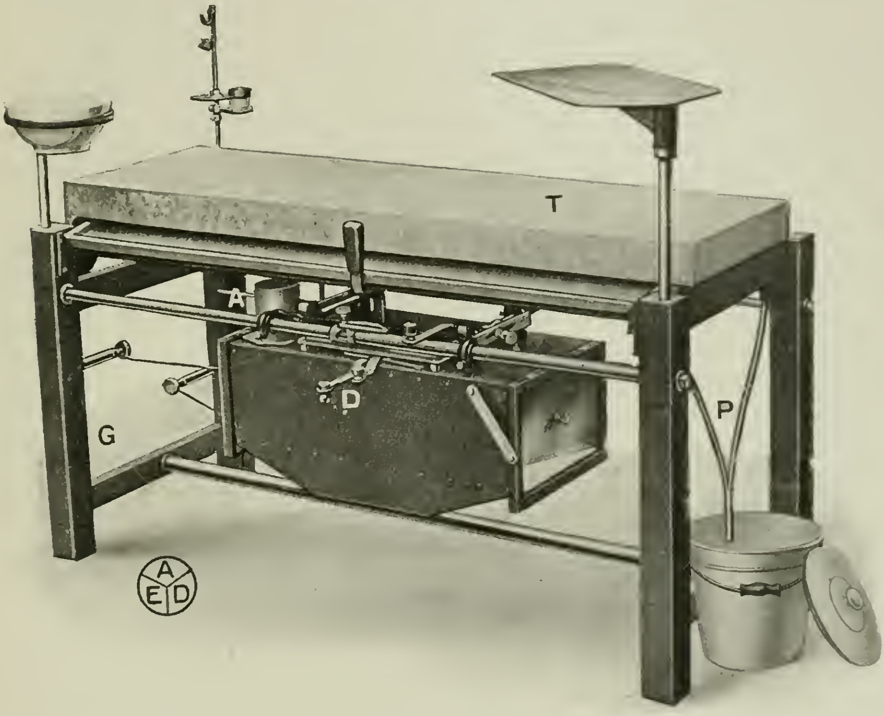


FIG. 113.—Atlas X-ray and operating table. (A. E. Dean.)

A. Antennæ which push the insulators free of the tube-box when in the distal positions.
D. All-metal protective tube-box.
G. Gate carrying the leading-in wires.
P. Tubes conveying any fluids from the gutters below table top.
T. Aluminium table top.

theatre. It is fitted as an operating table, combined with facilities for the use of X-rays. A localising device with a small screen and plumb-bob can be attached to the tube-box. Provided suitable darkening facilities are used, a small hospital or a private room can then have all the advantages of a powerful X-ray outfit for localising foreign bodies, and all the steps for their removal efficiently carried out. Such a combined apparatus is being prepared for the London district.

This mobile outfit provides for a plant with a dark tent for attaching to the waggon, but certain improvements are being made by which it is hoped the dark tent can be dispensed with. If the body of the waggon can be made large enough to form the dark chamber or X-ray room, this will be very convenient, and at the same time will save the trouble of having to erect a tent outside the waggon.

Although all these waggons, up to date, have been supplied with the dark tents, there is sometimes a difficulty in erecting the tent if a strong wind is blowing; also, if the tent is done away with, X-ray work can be carried on irrespective of the weather.

The motor is a 2-3 ton lorry, and has a 3 K.W. dynamo having an output of 20 amperes at 150 volts (or more could be provided).

The dynamo is driven from the main gear-box and is so arranged that it gives this output when running at normal engine speed, viz. 1000 revolutions per minute.

The dynamo is supported by a special frame which is fitted in the middle of the chassis and underneath the floor of the lorry. Protecting shields are made to keep out the dust and wet, and a suitable governor is fitted to the main engine.

Behind the driver's seat is situated the photographic dark room, which is arranged with a seat for the operator, a developing tank on one side, and a printing desk on the other; it is also provided with ample water supply, with hot drying cupboard, ventilator, lead-lined cupboard, dark room lamps, and all the necessary fittings.

Behind the dark room the remainder of the body is converted into either a store-room for the apparatus used in the tent outside or into a permanent radiographic dark room.

The chassis has an 11-ft. wheel base fitted with solid rubber tyres. A special feature of the gear-box is that a shaft extension may be made to drive the 3 K.W. dynamo direct from the main lorry engine. The dynamo is fitted under the floor of the lorry and the engine governed.

Three electric lights are provided, one for each compartment of the bodywork, and a large portable light for the tent, complete with wiring and controlling switches, also an electrically heated drying rack for photographic plates, combined with exhaust fan.

The covered body should be at least 12 feet 4 inches long by 6 feet 8 inches wide by 6 feet 6 inches at centre, divided into two compartments.

Compartment "A."—Dark room in front of body measuring 6 feet 8 inches by 3 feet 8 inches, and with a door in the centre. This will be provided with a lead-lined sink, fitted with a waste pipe and overflow, and with a removable rocking-board for developing trays; a 40-gallon water-tank under the sink arranged with a semi-rotary pump to raise the water to the tap over the sink. Hypo bin, lead-protected photographic plate store, cupboard for dishes and photographic apparatus, etc., bottle racks and two dark-room red lights, folding seat for photographer.

Compartment "B."—Store room, measuring 8 feet 8 inches by 6 feet 8 inches. This compartment will accommodate the apparatus to be carried, and a rack can be provided for X-ray couch, also a locker seat for attendants. A portion could be, if necessary, partitioned off and fitted with a door opening outwards into the interior of the tent, in which could be installed the

X-ray low-tension switch-gear, and control-switches and fuses for the dynamo.

The Tent.—This should be capable of being erected in a few minutes, and the dimensions would approximate to 12 feet 8 inches long, 8 feet wide, and from 7 feet to 9 feet high, the entrance being at one end. A light steel framework should be provided with suitable fittings, so arranged that the side and roof will roll up on a light pole, and be strapped to the channel on the roof. The material of the tent will be double-texture rubber-lined waterproof canvas.

There is provided, also, a 50-volt accumulator which can be used alternatively with the dynamo provided.

(*b*) **The Collecting Hospital or Clearing Station.**—This outfit should be more or less a stationary one, with ample conveniences for photographic work; but at the same time the apparatus should be arranged to allow of quick transport from place to place when the forces are moving rapidly.

The following apparatus should place a useful outfit in the hands of the radiographer: (1) Electrical Supply. To obtain the necessary electrical supply the choice lies between (*a*) accumulators and (*b*) petrol engine and dynamo. The latter is undoubtedly the better, though it is a good plan to include a set of accumulators which can be charged from the dynamo. The petrol engine and dynamo are mounted on a combination bed-plate; a magneto ignition, carburettor fuel tank and radiator should form part of the set. At a speed of 700 revolutions per second the apparatus should generate 1 kilowatt or 100 volts and 10 amperes. The whole should be completed with shunt regulator switch-board for charging accumulators, and there should be a radiator for cooling purposes. This set should be arranged for direct connection to the X-ray apparatus. (2) A set of portable accumulator batteries consisting of six cells and 50 ampere-hour output. (3) A 12- or preferably a 15-inch portable coil with subdivided primary with a condenser and a small moto-magnetic interrupter; this will be found useful as a second break when the larger one is out of action. The coil should be fitted into a strong outer wooden case for transport. (4) The interrupter should be of good size, and one of the many mercury jet interrupters will be most suitable. The motor should be wound to work at 100 volts on direct current, which is derived from the petrol electric set. (5) A small switch-board and rheostat with the auxiliary control switches should be included. This may be arranged in the form of a box, which, when closed, allows of ready transport. (6) A simple tube-stand with mechanical movements is necessary. It should be readily taken to pieces if required. (7) An X-ray couch. This should have folding legs, and should be light and fairly rigid. It should be constructed so as to allow of screening. (8) X-ray and valve tubes. It is well to have a good supply of these. When it is necessary to have the installation removed to another base they should be packed in large boxes, and should be suspended from the top or sides of the box so that they may not easily be broken in transit. Three to six tubes will form a good set for ordinary use. (9) A fluorescent screen fitted with lead glass and protective rubber handles. Also several pairs of lead-lined gloves will be necessary. (10) Intensifying screens with cassettes. A simple form of localiser should be included. (11) Photographic conveniences: these must be left to the calls of the particular place the installation has to serve. When a dark room is not available it must be provided for. A small dark room may be constructed of wood built in sections, or a tent may be requisitioned. The fittings should consist of lead-lined benches, with sink and waste pipe. A water-supply can be connected to the sink if such is available. A good supply of flexible tubing will be found useful when water has to be brought from a distance. A dark-room lamp with a safe light should be

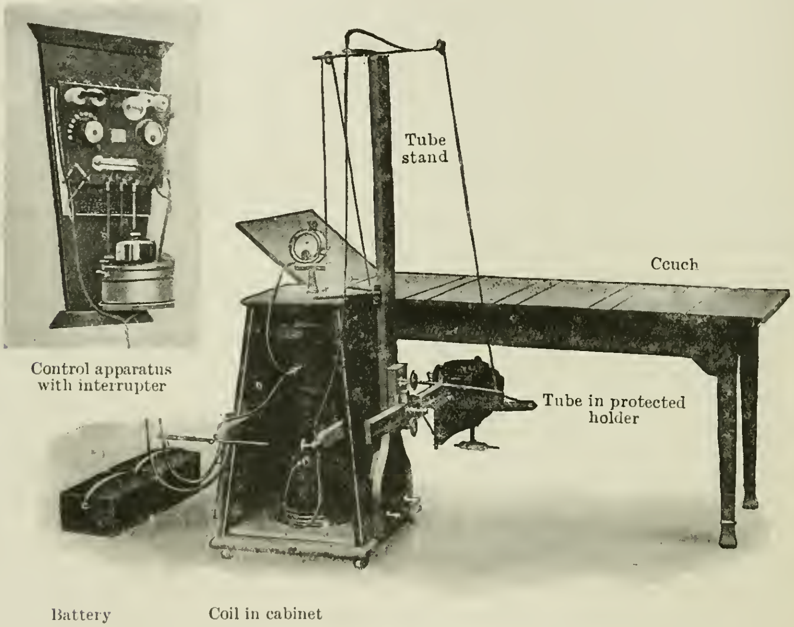


FIG. 114.—Portable X-ray installation arranged for radiography from beneath couch. (Medical Supply Association.)

included. A candle will give sufficient illumination. Developing dishes of sizes up to 12 inches by 14 inches, also draining racks, etc. (12) A supply of X-ray plates and X-ray paper. The latter is useful when it is not convenient to use plates. An X-ray paper for direct radiography has been prepared. This, though not so good as the plate, is much more convenient for transport. (13) A supply of chemicals. The tabloid developers are very useful, as they are readily made up in a few minutes. The installation may be varied according to the needs of the radiographer, the important point being to provide a high standard of efficiency, combined with the possibility of rapid movement if such be required. The efficiency will depend upon the knowledge the operator has of his apparatus. He should be conversant with the mechanical details of all parts, and should be able to pack, reinstall, and get it into working order quickly. Practice will soon enable him to do all that is necessary. When a large amount of work has to be done, assistance must be available. One or more medical radiographers should accompany each installation, and several orderlies or nurses must be trained to carry on the work at any time.

In the case of large armies there must necessarily be many installations working at various places. To facilitate rapid work a system must be employed.

The difficult cases may be transferred to the hospitals at home if the patient is in a condition to travel and the symptoms are not urgent. By doing this the collecting hospitals are relieved of heavy work, involving much time, and are able to attend to the more urgent cases as they come in.

For localisation of foreign bodies several methods may be used ; these are fully described later in the chapters dealing with localisation.

FIG. 115.—Portable X-ray installation packed ready for transit. (Medical Supply Association.)

(*c*) **The Field Outfit.**—The essential is portability. The best arrangement for work on the field is a small but serviceable installation fitted up in a motor transport, the engine of which can be used to drive the dynamo which generates the electricity. By this means a more powerful installation can be used than when dealing with accumulators. The whole apparatus can be fitted up in a motor ambulance waggon, a portion of which can be screened off to form a small dark room.

Necessary Apparatus.—(1) A dynamo, (2) mercury jet interrupter, (3) 15-inch coil, (4) X-ray couch with all accessories, (5) tube-stand with mechanical movements, (6) fluoroscope for screening, (7) plates, tubes, and dark-room requisites.

An extremely compact and portable outfit is illustrated in Figs. 114 and 115. It is most suitable for field work when petrol engine and dynamo are not available. It combines portability with considerable efficiency. It consists of :

(*a*) Set of accumulators.

(*b*) Hand-worked or motor-driven interrupter (the latter being preferable), which controls the current derived from the accumulators.

The method used for obtaining the required speed from the hand-worked interrupter is somewhat ingenious, a cylindrical weight inside the interrupter giving the effect of a fly-wheel, and permitting a regular speed to be obtained.

In place of the hand-driven interrupter the latter may be connected to the electrical supply, or if accumulators are used, an extra battery should be provided to drive the interrupter.

(*c*) Coil enclosed in a cabinet which is arranged to form a complete case for the whole outfit.

(*d*) Tube-holder combined with the cabinet.

The small portable set when not in use for field work may be used for radiography of cases in the wards of the hospital. There are many patients who are not fit to be moved to the radiographic room ; such cases can conveniently be done in bed when a portable set is available.

PRODUCTION OF THE RADIOGRAPH

The question of exposure in radiography is one which is ever before us. How long an exposure must we give for a particular region ? Before making a statement on the question of time it is necessary to consider the various factors which govern the exposure.

The Plate or Film Employed

This is the first point for consideration. X-ray plates are specially prepared for radiographic work, and any of those on the market are good. In this country the most suitable and best known are those of Ilford, Wellington, Warwick, Wratten, and the Barnet. The emulsion is spread over a sheet of glass, and the plate is enclosed in two light-tight envelopes. A second envelope is used to avoid the danger of fogging, when one only is employed, by accidental admission of light or through pin holes in the paper.

These special X-ray plates are expensive, so when a large amount of work has to be got through a cheaper plate may be used for the detection of fractures of the extremities. When fine detail is not essential, as in determining the presence of a fracture or dislocation, any ordinary photographic plate can be used. The plate may be placed in a special cassette, in which case the black envelopes are not required. Care must be exercised in the dark room, when opening a box to take out a plate, to make sure that the light is " safe."

When the dark room is in close proximity to the radiographic room, some form of protection must be employed to prevent the plates from being fogged by X-rays. A box lined with several millimetres of lead will be sufficient to serve for the protection of these.

Of recent years plates have been made much more sensitive and therefore speedier, but an even faster plate is still desirable.

Exposure

The length of the exposure depends upon :

(1) The quality of the tube and the degree of penetration.

(2) The strength of the current employed, the size and quality of the coil, and the type and frequency of the interrupter.

(3) The thickness of the subject.

(4) The distance of the tube from the plate.

(5) The rapidity of the X-ray plate.

The Quality of the Tube.—The operator must know the quality of his tubes well. A very hard tube should rarely be used if good radiographs are required. A soft tube will give good detail in all the parts, but particularly of the soft parts, where a diagnosis is required of their condition. For fine detail in bones it is better to give long exposures with a moderately soft tube, and trust to the increase in the time to give the necessary detail.

The choice of tube for various parts is often a matter of difficulty, and it is necessary to have a number of tubes in varying states of hardness in order to be able to select the proper tube for special parts. The Coolidge tube, however, can quickly be adjusted to meet almost any of the requirements of radiography.

The Intensity of the X-rays is in proportion to the penetrating power of the tube multiplied by the number of milliamperes used. With one and the same tube, 1 milliampere for 60 seconds, or 2 milliamperes for 30 seconds, or 10 milliamperes for 6 seconds should produce the same effect on a plate. If tubes of different penetrating power are used, the number of milliampere-seconds required with a soft tube may be three to five times as great as that required with a hard one. To produce a certain density on a plate, 30 seconds' exposure with a current of 2 milliamperes may be sufficient with a hard tube, whereas with a soft one either 150 seconds may have to be given with a current of 2 milliamperes, or else 30 seconds with a current of 10 milliamperes.

The next factor in the calculation of the exposure is **the thickness of the subject.** Chest and abdomen, for instance, may have the same thickness, but if the latter requires 200 milliampere-seconds, 50 to 80 milliampere-seconds may be enough for the former, because the chest contains the lungs filled with air, whereas the contents of the abdomen have a greater atomic weight. For the same reason the head requires more milliampere-seconds than the chest, though both may have the same thickness. The intensity of the X-rays is in inverse proportion to the square of the **distance.** While one is aware that any increase of distance means prolongation of the exposure, it is a good point to get a good distance away from the plate. The farther the distance between the anti-cathode and the plate up to a limit of about 6 feet the sharper will be the resulting radiograph. At the distance of 6 feet a natural-sized picture is obtained, with practically no distortion. This distance may be employed when the exact size of an organ like the heart is desired; a good average working distance is about 2 feet for parts of average thickness.

A *slide rule* enables us to find out the necessary exposure approximately. The first scale contains figures for the distance between anti-cathode and plate, varying from 12 up to 200 cm. On the second scale, figures for the thickness of the object, varying from 2½ up to 50 cm., will be found. On the third scale is the penetrating power of the tube in Wehnelt units, from 2 up to 18; and the fourth scale contains the figures for the milliamperes used, and rises from 0·5 up to 50 milliamperes.

By adjusting the two slides so that the figures for the distance, thickness, penetration, and current which are being used are opposite to one another, the index on the second slide points to the number of seconds required for the exposure, which is on the fifth scale, beginning with $\frac{1}{4}$ and rising up to 120 seconds.

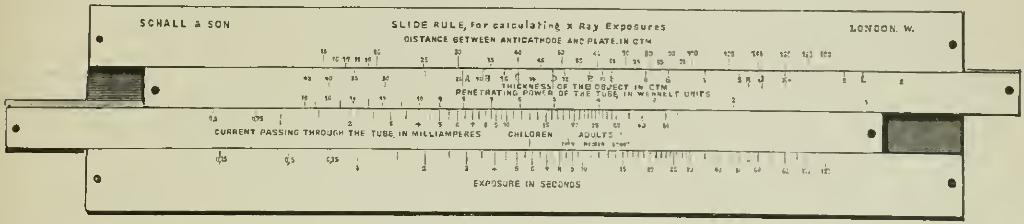


FIG. 116.—Slide rule.

On this basis it is possible to set down an Exposure Table which shall be of some practical utility to the beginner. There are of course so many special conditions that come into the matter that it is not possible to lay down hard and fast rules. Actual experience with the outfit and tubes is essential, combined with the exercise of good judgment. The following table will therefore only be taken as a guide, remembering always that if the tube be softer or the distance greater the exposure must be correspondingly increased. The exposure must also be increased for abnormal stoutness, and so on. Above all, each focus tube, no matter what its degree of hardness, must be worked to just that extent which signifies maximum efficiency, neither under-running nor overstraining. This point is dealt with fully in the chapter on Tubes.

Object.	Distance from plate to anti-cathode.	Penetration.		
		Wehnelt Scale.	Benoist and Bauer.	M.A. Seconds.
	Inches.			
Skull, occipito-frontal	18	9-10	6-7	150
Skull, transversely	18	9-10	6-7	140
Skull, teeth (with film inside), mouth	15	8	5	15
Cervical vertebræ	18	8-9	5-6	70
Shoulder	18	7-8	5	80
Thorax	18	7-8	5	80
Lumbar region	18	8-9	5-6	180
Ribs	22	8-9	5-6	75
Knee-joint	22	8	5	70
Femur	18	9	6	90
Ankle and foot	22	6-7	4-5	30
Wrist, hand	18	6	4	12
Stomach (Bismuth meal)[1]	...	...	...	...
Kidney	18	6-7	4-5	180
Pelvis	24	9-10	6-7	200
Hip-joint	24	9-10	6-7	180

[1] This is usually taken with an intensifying screen. The exposure varies with the apparatus used.

The milliampere-seconds are obtained by multiplying the time of exposure by the number of milliamperes used.

The above exposures are calculated without intensifying screen. If a screen be used, the exposures are reduced to about $\frac{1}{10}$th or $\frac{1}{12}$th.

Rapid radiographs in one or two seconds, or even fractions of a second, are secured by powerful intensified coils of, say, 16-inch spark length running with centrifugal motor mercury interrupter, utilising a heavy primary current, and in conjunction with a good heavy-anode tube that has been well tuned up. After practical experience, and after becoming a thorough master over the peculiarities of his own outfit and his own focus tubes, the beginner will soon find that he is able to reduce exposures very considerably all round.

The type of tube used is also a factor in the time of exposure. The tungsten target tubes appear to give a somewhat more penetrating ray than the platinum target tube which has up to quite recently been almost universally employed; this may in part be due to the more complete exhaustion of these tubes in manufacture.

With a single-impulse apparatus radiographs of the chest may be obtained when an intensifying screen is used in $\frac{1}{100}$ of a second. The more recent forms of this apparatus enable the worker to obtain good radiographs of moderately stout patients in this time. Single-impulse radiograms of the abdomen can also be obtained if the patient is not too stout; when the body is too thick recourse must be had to comparatively short-time exposures. With an automatic cut-out switch $\frac{1}{10}$ or $\frac{1}{4}$ of a second may then be sufficient. The aim of all workers is to produce instantaneous radiographs without the use of the intensifying screen. The Coolidge tube, with its capacity for passing heavy discharges, may be a means to this end, but this tube requires special consideration in exposures. F. H. Kuegle, M.D.,[1] gives useful information for the management of the exposures with a Coolidge tube, when used in conjunction with a high-tension transformer, in radiography of bones. The details of the technique consist in selecting that button of the rheostat which will give a milliamperage varying between 9 and 11, when the heating current is adjusted to back up a spark of $3\frac{1}{2}$ to $4\frac{1}{2}$ inches. By slightly changing the filament temperature it is easy to secure the desired penetration for any part. An elbow requires, say, 11 milliamperes with a spark-gap of $3\frac{1}{2}$ to $3\frac{3}{4}$ inches; a shoulder, 10 milliamperes with a spark-gap of 4 inches; a thick hip or head, 9 milliamperes and a $4\frac{1}{2}$-inch spark-gap.

When working on these lines the rheostat button which will comply with the above requirements will vary with different transformers, but once the proper selection has been made it should be possible to produce fairly constant results, as one need only place the rheostat control on, say, button 7, adjust the filament temperature to 9, 10, or 11 milliamperes, measure the thickness of the part, refer to a graduated table, and make the exposure.

All exposures should, if possible, be made at a uniform distance of, say, 60 cm. between the anti-cathode and the plate.

[1] "Technique with the Coolidge Tube," in the *American Journal of Roentgenology*, May 1916.

Dr. Kuegle gives the following table for the three kinds of plates he uses:

Thickness of Part.	Paragon Plate.	Seed Plate.	Cramer Plate.	Screen.
Cm.	Time (Sec.)	Time (Sec.)	Time (Sec.)	
1	1½	2	2½	
2	2	3	4	
3	3	4	5	
4	4	5	6	
5	5	6	8	
6	6	7	9	
7	7	8	10	
8	8	9	11	2
9	9	10	12	2½
10	10	11	14	3
11	12	12	16	3½
12	13	15	17	4
13	14	16	19	5
14	16	17	21	5½
15	17	19	22	7
16	18	21	23	9
17	20	23	25	10
18	22	25	27	11
19	24	27	29	12
20	26	29	31	13

Gregory Cole gives the following data for exposure with a Coolidge tube:

Part of Body.	Length of Spark-Gap in Inches.	Milliamperage.	Time in Seconds.	Milliamperage. Seconds.
Hand, soft parts	1½-2	25	2	50
Hand, bone	2	25	2	50
Foot, soft tissues, lateral	2	25	3	75
Foot, bone, lateral	3	25	3	75
Knee, soft parts	3	25	4	100
Knee, bone and soft tissue	4	25	4-5	125
Knee, bone only	4½	30	5	150
Shoulder, soft tissues	4	30	8	240
Shoulder, bone	4½-5	30	10	320
Hip, bone	5	30	15	450
Kidney	4	30	15	450
Spine, bone, detail	5	30	15	450
Head, lateral	5	30	15	450
Head, A.P.	5½	40	15	600
Lungs	3	40	10	400
Stomach (Screen)	5	100	·06	6

EXPOSURE TABLES

Comparison of Different Radiometers

Benoist	2	2½	3	4	5	6	7	8	9	10
Benoist-Walter	1	2	3	4	4½	5	5½	6	..	..
Walter	2-3	3-4	4-5	5-6	6	6-7	7	7-8	..	..
Wehnelt	1·8	3·3	4·9	6·5	7·2	8	9	10·5	13	15
Bauer	1	2	3	4	5	6	7	8	9	10

The Intensity of the X-rays varies with the Distance between the Anti-cathode and the Plate.—The intensity of the X-rays is in inverse proportion to the square of the distance. If we have to expose for a certain object 3 seconds, with a distance of 10 inches between the anti-cathode and the plate, the time of exposure required with 10, 12, 16, 20, 25, 30, 40, 50, 60, 80 inches will be 3, 4·32, 7·68, 12, 18·75, 27, 48, 75, 108, 192 seconds; or, expressed in other figures:

Distance	10	14·1	17·3	20	22·4	24·5	26·4	28·3	30 cm.
Exposure	10	20	30	40	50	60	70	80	90 M.A. seconds.

The distances usually chosen are:

For teeth, toes, fingers, or hands . .	10 to 12 inches.
Arms, neck, leg, or foot	12 ,, 15 ,,
Nose, head, shoulder, knee . . .	20 ,, 22 ,,
Chest, kidney, pelvis	22 ,, 25 ,,

The distances given are approximate only. When the subject is fairly thick it may be necessary to have the tube at a greater distance; also, when the object from a diagnostic point of view is likely to be obscured by shadows thrown by structures in front of it, it will be found advantageous to have the tube close to the surface of the body.

In order to further aid in the estimation of the exposure in different objects and parts a table accompanies the list of illustrations. This is based on practical experience with the outfit described.

By carefully noting the data and comparing the result it is hoped that the beginner may be helped in the estimation of exposure. It must be noted that the greatest possible care must be taken in the technique of development to produce good results. It is very easy to nullify the advantage of proper exposure by faulty photographic technique.

Caution

The distance chosen depends upon the thickness of the subject. At the longer distances we must employ apparatus of greater power if short exposures are required, such as an intense single-impulse coil, or one of the forms of high-tension rectifier. The additional advantage of working at long distances from the tube is that both the patient and the person screening are less likely to be damaged by the X-rays.

Care must be increased when working at a short distance, especially when repeated examinations of a particular patient are required, that the patient is not damaged. If work must be done at a close range it is wise to have in front of the tube a screen of aluminium 1 mm. thick. This does not cut off any of the penetrating rays, but absorbs the softer ones, which are likely to damage the skin. It is important to always remember, especially when using the heavy discharges from transformers and large coil outfits in conjunction with a Coolidge tube, that there is an element of danger so far as the patient is concerned. It should always be realised that dermatitis may be produced if a number of these heavy discharges are used over the same skin area. Currents of 40 or 50 milliamperes for 10 or more seconds should not be used repeatedly over the same surface. It is a good plan to estimate the skin dose given with these exposures and if the danger point is reached then no further exposure should be given until time has elapsed sufficient to allow of the recovery of the part. The chief consideration is to make sure first of the dose given with each exposure; secondly, to always work at a distance sufficiently great to obviate any danger. A thin filter of aluminium will protect the skin from the soft radiations and will not seriously interfere with the quality of the negative.

The exposure times given on page 136 are only approximate, and should not be taken as an absolute guide. They illustrate the principle of exposures rather than the practice. Conditions vary with different forms of apparatus, consequently the operator must clearly understand his outfit, particularly the X-ray tube. When very rapid exposures have to be made the difficulty of accurate work is increased, there being no great latitude upon which to work. Single-impulse exposures, when an intensifying screen is used, are comparatively easy, but even here the correct condition of the tube must be obtained if perfect radiographs have to be produced. A tube a trifle too hard will give an over-exposure, while a soft tube will give an under-exposure. It is possible that when tubes constructed on the principle of the Coolidge tube come into general use, the technique of exposure will require to be largely remodelled.

The Adjustment of the Radiographic Plate

For X-ray examinations a special plate is employed. It is made more sensitive, and gives greater detail by reason of a thicker emulsion, containing more silver salt than the ordinary photographic plate.

The plate is placed in a cassette, or two light-proof envelopes, in the dark room, the film side of the plate being placed towards the object to be radiographed.

The centering of the plate is a matter of some importance, most modern couches having devices by which this may be done automatically. The best method of centering is one devised by Dr. Ironside Bruce, where the central ray from the tube can always be located by means of a plumb-line operating over the top of the couch. This may also be used for getting the centre of the plate exactly in the centre of the part to be examined.

The part of the patient to be examined should always be as close to the plate as possible. On the couch some form of compression must be employed to keep the parts as immobile as possible. When the screening-stand is used, the part is first examined by the aid of the fluorescent screen, and the diaphragm adjusted to cover the part required. The fluorescent screen is replaced by the X-ray plate in a cassette and clamped in position, and the patient may be fixed by a strong linen band or a bandage. The shorter the exposure the less risk is there of movement on the part of the patient spoiling the result.

The Use of the Intensifying Screen

Though negatives obtained by the use of the intensifying screen may not perhaps be of the same high technical quality as the best radiographs made by powerful installations without a screen, it should be noted that, when skilfully used, pictures so obtained with apparatus of moderate power are, from a diagnostic point of view, of much greater value than those obtained without a screen. This is especially the case when radiographing parts of the body where movements are constantly going on, as in the chest

a *b*

Fig. 117.—Normal hand to illustrate value of an intensifying screen.

(*a*) An intensifying screen was used for this radiograph, the exposure being $\frac{1}{10}$ of that for (*b*). The radiograph was considerably over-exposed.

(*b*) Taken without an intensifying screen with ten times the exposure. Note the detail in soft parts.

and abdomen. The plate must not be over-exposed, otherwise grain, due to contact with the screen, is bound to appear. A soft tube is also necessary when the screen is used, and it should be noted that there is not quite the same degree of latitude in the matter of exposure, but when all conditions are correct, radiographs so obtained can hardly be distinguished from those taken without the aid of the intensifying screen. This applies not only to the plate, but more particularly to the print, and a little experience with an average installation of moderate power and a screen will soon teach anyone how to obtain valuable diagnostic negatives, and enable the operator to do quick work, which would otherwise be beyond his reach.

For the purposes of diagnosis in regions such as the heart, lungs, stomach, or intestines, the value of radiographs so obtained cannot be overestimated, as with any of the modern intensifying screens it is quite possible to get results showing practically no grain.

It is most important that every care should be taken to avoid damage to the delicate surface of the screen, because any scratches or other markings causing an abrasion of the surface will certainly be reproduced on the negatives.

Before placing the screen in the holder it should be carefully dusted with a wide camel-hair brush. The film side of the plate is brought into contact with the fluorescent coating on the screen, care being taken to avoid rubbing the surfaces together. When making the exposure the film side of the plate should face the X-ray tube. When the screen is not in use it should be placed in such a position that it cannot get damaged or splashed with chemicals. The value of an intensifying screen is illustrated by the figures on the opposite page.

When a large number of plates are taken with an intensifying screen, it is useful to fix the screen permanently in the cassette and to use it only when rapid radiographs are required. A sheet of fine paper should always be placed over the screen and the cassette closed when it is not in use. A sheet of clean glass may take the place of the paper—both act as protectors of the fine surface of the screen.

Development

The general description of the dark room has been given in the chapter on the arrangement of apparatus, etc. It is essential to take the same care in the development of X-ray plates as is necessary in developing the fastest of ordinary photographic plates.

Specially prepared X-ray plates are slightly sensitive to red light, and care must, therefore, be taken to avoid more light falling on the plate during development than is really necessary. This can be accomplished in the following ways :

1. The employment of a carefully tested " safe-light " glass in front of the source of illumination. This screen must be tested in the conditions under which it will work ; thus, if electric light is used, a bulb of the same candle-power should always be used in the lamp.

2. The electric bulb may be immersed in a solution coloured by bichromate of potash and an aniline dye. To ensure greater safety the globe containing the lamp should be covered with a layer of yellow and ruby fabric. Provided exposure is not unduly prolonged, the X-ray plates may be developed in this light. The dark-room lamp should have in a convenient place a switch in order that the light may be turned off when developing the plate.

3. A cover to fit the developing dish may be placed over it immediately the plate is immersed, and not removed for several minutes, as it is in the early stages of development that plates are most easily fogged.

4. The plate may be developed in the dark.

The Choice of a Developer.—Any properly balanced developer can be used, the majority of workers using that recommended by the makers of the plates. Of these (1) Metol-hydrokinone, (2) glycine, (3) rodinol, (4) pyro-soda are the most commonly used, and each has its own advocate. The formula for one of the most largely used—metol-hydrokinone—is : Metol, 20 grains ; hydrokinone, 80 grains ; sodii sulphite (crystals), 2 oz. ; sodii carbonate (crystals), 2 oz. ; potassii bromide solution (10 per cent), 80 minims ; water, 20 oz.

The Preparation of the Developer.—(1) The metol must first be dissolved in 8 ounces of pure water (warm). When thoroughly dissolved the hydrokinone is added.

(2) The sodas and bromide are then dissolved in a further 8 ounces of warm water, the two solutions mixed, and made up to 20 ounces.

It is most important that each ingredient be allowed to dissolve thoroughly before the next is added. The developer is then allowed to cool, and to ensure the best results should be used at a temperature of 60° F. The following facts explain the reason for this insistence on a uniform temperature : Metol[1] and hydrokinone act differently on the photographic plate, metol being employed to obtain good detail, while the hydrokinone ensures density. The hydrokinone acts best at a temperature of about 65°, and becomes practically inert below 45°, and, therefore, in order to ensure that both agents act to the best advantage, it is necessary to work at about 60°. For this reason in cold weather the dark room should be kept at a little above 60°, and at a level temperature, in order that the dishes and solutions should not fall much below that temperature. In very cold weather, when plates are obtained which are lacking in density but show fine detail—when all other factors employed in the exposure of the plate have been favourable, and a good strong negative was expected—the explanation is often found to be a faulty temperature of the developer.

Caution.—If the metol is not allowed to dissolve thoroughly before the other chemicals are added, it will crystallise, and be precipitated in the form of granules. Should any of these settle on the plate during the process of development, small black spots with soft edges are likely to appear in those places where the granules have settled. Moreover, in using the developer improperly made up, the full strength is not available, and such conditions may account for failure to obtain the best possible results. A freshly made developer should be almost transparent in appearance and free from colour ; stale developer is from a light- to a dark-brown in colour. In hospitals and similar institutions, and with many radiographers, the practice is to have the developer made up by the chemist or his assistant, who does not understand the importance of extreme purity of chemicals and exact weighing, and so frequently sends up a hastily prepared developer which may spoil many otherwise good results. In large institutions a skilled photographer should be attached to the department, whose duty it should be to attend to the preparation of all solutions used.

When specially good negatives are desired it is a good plan to have a

[1] Since the outbreak of war substitutes for metol and hydrokinone have had to be found. These, however, prove to be quite as useful as the originals.

stock solution of sodium sulphite and carbonate in the proper proportions ready at hand. The metol and hydrokinone are then freshly prepared in warm water when wanted, and added as required, as is also the bromide solution. If these points are attended to, there should be no difficulty in obtaining really first-class negatives. The developing solution should not be used for more than three or four plates in succession ; if used too often it becomes oxidised by exposure to the air, and ceases to yield satisfactory results.

A developer which has already been used for a number of plates should not be kept for further use. Oxidation having commenced will continue until the solution ultimately becomes nearly black and quite useless. The freshly made metol and hydrokinone, if kept in properly stoppered bottles, will keep in good condition for a considerable time.

With normal exposures the image appears in about fifteen seconds, and development is complete in four to five minutes ; but in cases where the exposure has been very short, the image appears more slowly, and the time of development is proportionately longer. Where instantaneous exposures have been given, such, for instance, as $\frac{1}{50}$ of a second, development from fifteen to twenty minutes may be necessary in order to secure the desired results. Under these circumstances it is advisable to keep the developing dish covered over in order to avoid any possibility of fog from prolonged exposure to the dark room light during the process of development ; and the dish should be gently rocked until development is complete. The use of a very weak or highly restrained developer should be avoided.

Fixing

After development the plate should be rinsed for at least thirty seconds before placing in the following fixing-bath :

Hyposulphite of soda, 1 lb. ; potassium metabisulphite, $\frac{1}{2}$ oz. ; water to 80 oz.

If the fixing-bath is required for immediate use it is advisable to dissolve the potassium metabisulphite before adding the hypo, but hot water should not be used for the purpose.

Allow the negative to remain in the hypo bath until thoroughly fixed. and on no account examine a partially fixed plate by daylight, or stains will appear on the film which cannot afterwards be washed out.

If the plate is not washed free from developer before being placed in the fixing-bath, yellow stains will appear on the film which are very difficult to remove.

Washing and Drying

After complete fixation, the plate should be washed in running water for at least one hour, and then placed in a well-ventilated room, free from dust, until dry. If a negative is required for use immediately after development, fixing, and washing, it may be dried rapidly by the following method :

The surface moisture is first removed by allowing the plate to drain, or it may be carefully removed with a wad of cotton-wool or a pad of fine chamois leather. It is then placed in a methylated spirit bath for four or five minutes, and rocked as in development. It is then removed, and placed in a current of air or in front of an electric fan, when it will dry very rapidly, or it may be placed in a specially arranged drying-oven.

Reduction

It is sometimes necessary to reduce a developed plate which has been made too dense. The following solution will be found very useful for the purpose : Potassium ferricyanide, 120 grains ; water to 20 oz. A dram or two of this is added, just before using, to each ounce of ordinary hypo solution as used for fixing photographic plates, *i.e.* hypo, 4 oz. ; water to 20 oz. The plate is immersed in the reducer when it is to be acted on all over, or if for local use the solution is applied with a little tuft of cotton-wool. The plate after reduction is well washed and dried.

Intensification

Negatives which are not sufficiently vigorous owing to some error in manipulation may be greatly improved by the process of intensification. The film should first be hardened in the following bath : Formalin, 1 part ; water, 10 parts. In this bath the negative should be allowed to remain for five minutes, after which it should be rinsed for a few minutes, and then placed for exactly one minute in a bath consisting of potassium ferricyanide, 20 grains ; potassium bromide, 20 grains ; water to 20 oz.

Too long an immersion causes the image to bleach, and this should be avoided if it is desired to retain the original gradation. In the time prescribed there is no apparent change, but the clearing agent has done its work, which is the prevention of green fog in the subsequent process of intensification. The negative should now be rinsed for a few minutes, and then intensified in the following stock solutions :

(*a*) Silver nitrate, 800 grains ; distilled water to 20 oz.

(*b*) Ammonium sulphocyanide, 1400 grains ; hypo, 1400 grains ; water to 20 oz.

Half an ounce of (*a*) should be taken and added slowly to half an ounce of (*b*), stirring vigorously with a glass rod. Sufficient silver nitrate solution must be added until the precipitate formed is dissolved with difficulty. To this solution should be added : 1 dram of a 10 per cent solution of pyro preserved with sulphite, 2 drams of a 10 per cent solution of ammonia.

The negative should be placed in a chemically clean dish, and the solution poured over it. In a minute or two the deposition of the silver begins to take place, and as soon as sufficient density has been acquired, the negative should be placed in an acid fixing-bath until the slight pyro stain is removed. After this bath the negative should be well washed, and it is well, during washing, to lightly rub the surface of the film with a tuft of cotton wool to remove the slight deposit which will be found upon it. It is important that the negative to be intensified must have been thoroughly fixed in a clean, fresh hypo bath, and not merely have been left for some indefinite period in a stale or dirty solution of hypo that has been used on other occasions.

An alternative method of intensification is to bleach the washed negative in a saturated solution of perchloride of mercury, wash well, and then place in a strong solution of ammonia.

Printing

The printing of an X-ray negative is an art which is too often neglected by the radiographer. A well-finished print, nicely glazed and suitably mounted, is the work of the expert, and should always be aimed at, slovenliness here being quite inexcusable. It must be remembered that the average plate will produce a print which will explain the conditions found, and in the majority of cases it is on the print that the radiographer is judged. Consequently it should always be the aim to turn out a good print. The three papers commonly used in printing are :

(1) Bromide paper. (2) Gas-light paper. (3) Silver paper.

Nos. 1 and 2 are the most frequently used because of the conveniences they offer. The best prints are undoubtedly obtained by using P.O.P., the difficulty being, however, that a strong light is required, and the operator is dependent in the majority of cases on daylight conditions. When daylight is not available these papers may still be used by the aid of an arc lamp, by the use of which a negative may be printed in from ten to fifteen minutes.

The toning and fixing of prints so prepared is a little more troublesome than when papers (1) and (2) are employed, which possess the advantage over silver paper that they give the operator the opportunity of producing a good print by careful development, as by care in manipulation prints of good diagnostic value can be obtained from very indifferent plates. It must be insisted upon that the touching in of detail should never be practised in radiographic work. Though largely used in artistic photography, it has no field here.

In hospitals and in private practice, where large plates are used and several are taken of the same subject, reduced prints may be obtained by the use of a reducing lantern. By using an apparatus of this kind it is possible to obtain in a small space prints of the largest plates. These may be arranged in series on a large mount, and despatched to the physician or surgeon in charge of the patient. These reduced positives are quite sharp, show all the detail of the large prints, and may be included in the notes of a case. Plates when dried should be carefully cleaned and particulars attached to them. When examined and reported on, they should be filed away and indexed. The card index system will be found most useful for this purpose. Special cards may be printed to suit individual requirements.

Further Points in Exposure and Development

It is worthy of note that a practical knowledge of photography is very helpful to the radiographer, and in no part of his work more so than in the development of his plates. Fortunately for the majority of workers whose

An exposure of 12 secs.	An exposure of 28 secs.
10 „	24 „
8 „	20 „
6 „	16 „
4 „	12 „
2 „	8 „

Fig. 118.—To illustrate the latitude of exposure. Each of the twelve exposures gives a good negative. These exposures were made with a moderately soft tube.

knowledge of photography is slight, considerable latitude in the exposure time exists.

First Experiment.—In the course of a number of experiments performed for the purpose of ascertaining this point, it was found that if a limb of even thickness was radiographed, being divided into areas which allowed of twelve exposures of different duration, commencing with 2 seconds and ranging up to 20 to 30 seconds, useful negatives were obtained from each exposure.

The development was necessarily uniform, as all the exposures were on the one plate.

Second Experiment.—On this occasion the same duration of exposure was given to each part, and it was found that useful negatives were obtained by varying the time of development.

Third Experiment.—This experiment was carried out with a view to ascertaining the influence of temperature on the action of the developing agent. A wide range of variations was found which are very instructive. Using the same exposure for two plates and developing them side by side, one solution being about 20 per cent colder than the other, it was found that

FIG. 119.—To illustrate the latitude of exposure. Exposure with a hard tube.

at a temperature of 60° development was rapid, detail good, and density correct. If the temperature was below 45° the resulting picture showed detail, but little density, indicating that the hydrokinone had not been able to use its influence.

Fourth Experiment.—On this occasion variations in exposure were made, the times of exposure being as 1 to 5. The plate exposed for the shorter time was developed at 60° and the other at a low temperature. It was found that the first plate gave the better result.

These experiments indicate that by giving minimum exposures the wear and tear on apparatus and tubes is lessened, and the fogging of plates by secondary radiations minimised, while by proper manipulation of the developing solution better pictures are obtained. A further advantage of using the developer at a proper temperature is that we lessen the risk of fogging the plate by prolonged exposure to even a " safe ruby " light, and also the risk of chemical fog from prolonged immersion. These points have been elaborated with the intention of showing the advantage of working under proper conditions. It is hoped that they may explain some failures in cases where good results should have been obtained.

Instructions for glazing Gelatino-Chloride Prints

When the print has been prepared it is necessary to glaze and mount it on cardboard. Too great stress cannot be put upon this part of the work. A properly glazed and mounted print is the final effort of the radiographer.

The *Plate Glass* employed should be thoroughly cleaned in warm water and soda to remove dirt and grease, and then well rinsed in plain water to remove soda. Polish off carefully with spirits of wine, and soft leather. Sprinkle a little powdered French chalk, and again polish off *lightly* with soft leather.

Prints should be previously well hardened in alum or formalin. If alum is used, the solution should be filtered before use, and the print well washed after. If formalin is used, a short washing will suffice.

Place the print direct from washing-water on to the glass, one corner first, allowing the surface to roll into contact ; the action of the water will then exclude air bells. Or the print may be placed on the glass entirely under water. Lay the glass on a firm flat table, cover with a piece of clean, smooth blotting-paper, and squeeze lightly with a rubber roller. Heavy pressure should *not* be used, but merely sufficient to remove the surplus water, leaving the print in actual contact with the glass.

Backing.—Cut a piece of waterproof backing paper a little smaller than the print. Paste with stiff brush evenly and thinly, and squeeze lightly into contact with the back of the print on the glass. Leave till thoroughly dry. Then insert the point of a knife under the edge of the print, when it will strip off with an enamelled surface.

STEREOSCOPIC RADIOGRAPHY

The localisation of a foreign body by means of X-rays is now so generally adopted, and so many methods, many of them brought forward as new. are recommended, that there is a danger of the stereoscope, one of the earliest and best methods, being overlooked or laid aside.

Sir James Mackenzie Davidson has recently shown the fallacies of the single-plate method of demonstrating the presence of a foreign body, and has called attention to the stereoscopic method which he has so ably practised for many years; this method, when combined with a mechanism for measurement, such as the cross-thread method, is still one of the most reliable procedures for the exact localisation of a foreign body.

The question which presents itself to the practical radiologist at the present time is how far can he go in aiding the surgeon to localise the body and subsequently remove it from the patient. In other words, by what means can he render help to the surgeon which will be at the same time accurate and time-saving. As explained in the chapter on Localisation, the radiologist's most efficient aid can be rendered in the operating-room where exact localisation can be carried out immediately prior to the operation. Precise information can be given as to the presence of a foreign body—its depth from the skin surface and the exact spot under which it lies is indicated by a mark on the patient's skin. This appears to be perfectly simple, and in a large number of cases it is all that is required; but there are cases where difficulties occur and the foreign body is not so readily localised and removed.

The surgeon, in order to be successful, must have a clear conception of the exact situation in which a foreign body lies, its depth from the surface, and, what is more important, its relationship to well-known landmarks in its immediate vicinity. With such data he should never fail to remove a foreign body which is surgically accessible; if it is not so the removal should not be attempted.

The question at once arises as to the most reliable method by means of which he can obtain this information. A mere statement, in the form of a report, that the foreign body lies so many centimetres below a given point (marked on the skin) is not sufficient; indeed it is often misleading and occasionally leads to failure. Stereoscopic plates, recently taken and placed in the stereoscope, will give the surgeon the information he requires in a concise form, enabling him to visualise the foreign body, its exact position, and its relationship to structures in its vicinity. With this picture before him he proceeds to perform the operation.

When observing any object or group each eye sees quite a different picture, but the two images thus seen are combined into one picture by the brain, which has the property of perspective. To radiograph stereoscopically with accuracy, therefore, it is necessary that the points of view should be the same distance apart as the pupils of the two eyes, but in radiography it has been found that to produce the best relief it is necessary to exaggerate the stereoscopic effect.

The stereoscopic method has the great advantage of enabling us to view the picture from two points of view, a matter of the utmost importance when surgical measures are contemplated.

The customary methods employed in stereoscopic radiography will require to be considered briefly.

Two plates are taken from different points of view—the plates occupy the same relative positions below or above the patient according to whichever method is employed. The first plate is placed in position ; the tube, accurately centred in the tube-box and adjusted so that the central rays pass through the foreign body, is then moved 3 cm. to the left side and an exposure is made ; this plate is marked " left shift of the tube." A second plate is placed in exactly the same position as the preceding one, the tube is now moved 6 centimetres to the right, and the plate is marked " right shift of tube."

It is of the utmost importance for the accuracy of subsequent examinations that the plates should be carefully marked according to the displacement of the tube.

In cases in which this has been overlooked or the mark has been obliterated, it is still possible to ascertain the direction of the " shift." A prominent anatomical point on the negative can be taken to determine this shift ; the distance of this point from the edge of the plate is measured and compared with a corresponding point on the other negative ; that which shows the shorter distance will indicate that the tube has been moved in the opposite direction. In estimating the distance it is well to take a point on the negative which has had a considerable displacement ; for example, if a shoulder is under examination and the plate is on the posterior aspect, then a point on a higher plane than the posterior part will show a large displacement. In such an instance the coracoid process would be a good point from which to measure the distance. The explanation is obvious if one conducts a simple experiment. A pencil is held at a distance of two or three inches from a piece of paper, then a lighted match (A) is held vertically over the pencil and the shadow falls directly below the pencil (D) ; next move the lighted match to the

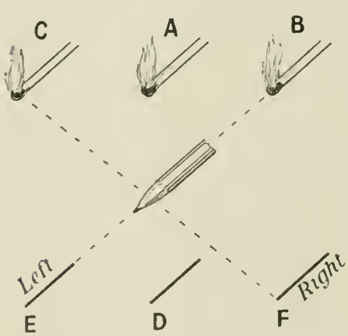


Fig. 120.—Diagram to illustrate the stereoscopic method.

left side (B), and the shadow falls to the right (E); then move the match to the right side (C) and the shadow will be seen to move to the left (F); mark these shadows right and left and the explanation becomes obvious. Now substitute a foreign body or an anatomical structure for the pencil, an X-ray bulb for the lighted match, and we have reproduced the appearances and displacements seen in stereoscopic radiographs.

When a Coolidge tube is used in conjunction with an extension tube the light from the heating filament may be used as a means of estimating the degree of the displacement of the tube.

The extent of the displacement of the tube should vary with the thickness of the object if clearly defined stereoscopic plates are required. For the examination of small objects, such as the finger, the wrist-joint, etc., it is convenient to take the two radiographs on one plate; when finished it may be viewed in a hand stereoscope. The correct degree of movement for the tube has been calculated by Marie and Ribaut, who have given the following table, but this need not be absolutely followed if the movement of the tube is recorded.

Marie and Ribaut's Table

Thickness of part to be radiographed.	Distance of the Anti-cathode to the surface of the Body.				
	20 cm.	30 cm.	40 cm.	50 cm.	
cm.	cm.	cm.	cm.	cm.	
2	4·4	9·6	16·2		
4	2·4	5·4	8·8	13·5	
6	1·7	3·6	6·1	9·3	
8	1·4	2·8	4·1	7·3	
10	1·2	2·4	4·0	6·0	Distance to which the tube must be displaced.
15		1·8	2·9	4·3	
20		1·5	2·4	3·5	
25		1·3	2·1	3·0	
30		1·2	1·9	2·7	

In practice each operator will find that a little care in determining the exact extent of the displacement for different objects will greatly add to the value of the stereoscopic plates he produces.

After the exposure and subsequent development the two images must be optically fused into one, and for this purpose there are many forms of instrument, such as the Wheatstone and the Scott-Dean reflecting stereoscopes, and the Pirie hand stereoscope. The pictures can be reduced and viewed in a hand stereoscope.

Good stereoscopic negatives, when viewed in position, show perfect pictures, with the correct perspective for the parts shown, though the exact localisation of a foreign body may be difficult or in some instances impossible. A **Wheatstone stereoscope**, or its modified Scott-Dean form, should be employed whenever possible as it affords valuable aid, by means of its adjustable parts, in quickly getting the correct position of the plates. When this comparatively elaborate stereoscope is not available, a Pirie hand stereoscope will be found useful.

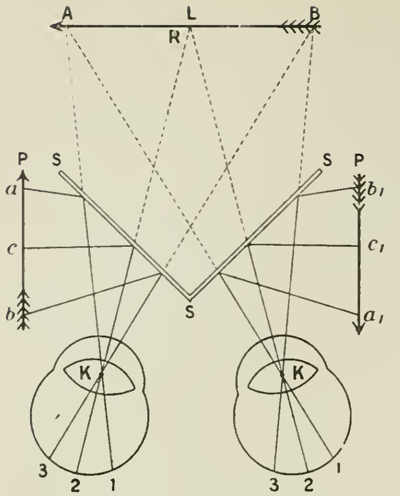


FIG. 121.—Diagram to illustrate the principle of Wheatstone's reflecting stereoscope. (From *Ency. Brit.*)

K K, right and left eyes; *S S S*, mirrors; *P P*, objects in position; *a b*, picture on left side; b_1 a_1, picture on right side; 3 2 1, corresponding points on retina; *A L B*, object as seen in relief in mirrors; *b*, picture seen by left eye in position *B*, and image on retina at 3; *c*, seen at *L R*, and retinal image at 2; *a*, seen at *A*, and retinal image at 1; a_1, seen at *A*, and retinal image at 1; c_1, seen at *R L*, and retinal image at 2; b_1, seen at *B*, and retinal image at 3.

Another form of stereoscope which is of great value in X-ray work is that introduced many years ago by Sir David Brewster. The instrument is very convenient for the inspection of reduced pictures of stereoscopic radiographs. These are readily produced in a reducing lantern. For small objects, such as fingers, wrists, temporal bones and accessory sinuses, the pictures may be produced on small plates, lantern size, directly from the subject. By means of a simple plate-changing device the two pictures may be obtained on one plate. These may then be inspected with a **Brewster stereoscope.**

The principle of the Brewster stereoscope is explained by the diagram on page 151.

This form of instrument may also be used for the inspection of stereoscopic illustrations in books by removing the portion of the stereoscope which generally holds the plates or prints.

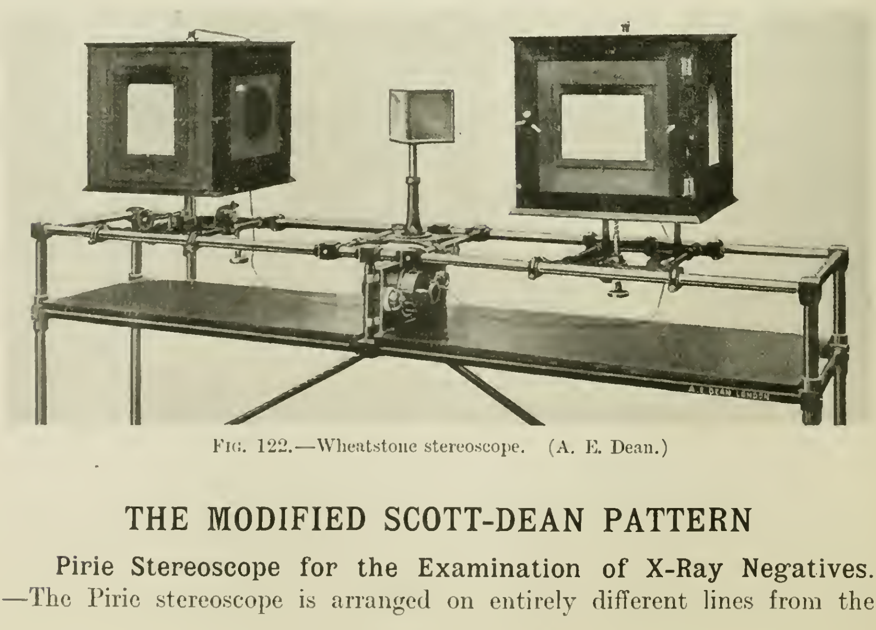


FIG. 122.—Wheatstone stereoscope. (A. E. Dean.)

THE MODIFIED SCOTT-DEAN PATTERN

Pirie Stereoscope for the Examination of X-Ray Negatives. —The Pirie stereoscope is arranged on entirely different lines from the instruments which have been heretofore employed for the examination of stereoscopic X-ray negatives. Instead of using reflecting mirrors, a double reflecting prism is used. For convenience the prism is mounted in one of two metal tubes, which are bound together by a connecting piece, the second tube being a plain one only, and serving to exclude extraneous objects from view. The stereoscope is light, the metal part being constructed of aluminium, and can be easily carried in the pocket. A feature of the Pirie stereoscope is the ease with which stereoscopic vision is obtained. It frequently happens that persons who are not accustomed to examining stereoscopic negatives wish to do so, and with the old form of reflecting mirror stereoscope this has always been a difficult matter, very often ending in failure. With the Pirie stereoscope, however, it is almost impossible for any one to avoid seeing the negatives stereoscopically. The negatives are taken in the usual manner and are placed side by side, either in suitable boxes provided with electric light, or they can be rested on the framework of a convenient window.

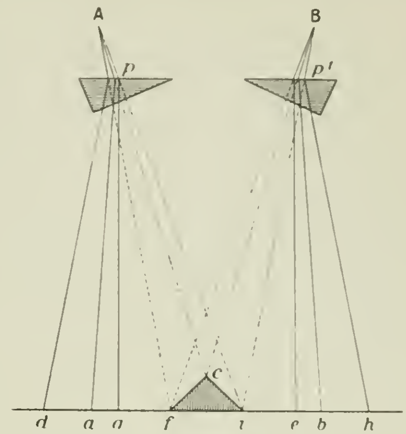


FIG. 123.—Diagram to illustrate the principle of a refracting stereoscope. (From *Ency. Brit.*)

A, left eye; *B*, right eye; *a*, *b*, corresponding pictures for each eye; *p*, p^1, prisms of glass. The prism *p* refracts the ray *ap*, in the direction of *pA*, as if it proceeded from *c*; thus *a* and *b* combine to form the point *c*; *d* and *e* combine to form the point *f*; *g* and *h* combine to form the point *i*.

The distance at which the negatives are observed depends upon the distance between the centres of the negatives, that is to say, the size of the plates. For instance, the best position to inspect a pair of 12-inch by 10-inch negatives placed as closely together as possible is about 3 feet 6 inches. When looking at smaller negatives it is necessary to come much closer in order to obtain a comfortable stereoscopic effect, or with larger negatives the distance must be increased.

FIG. 124.—Pirie stereoscope.

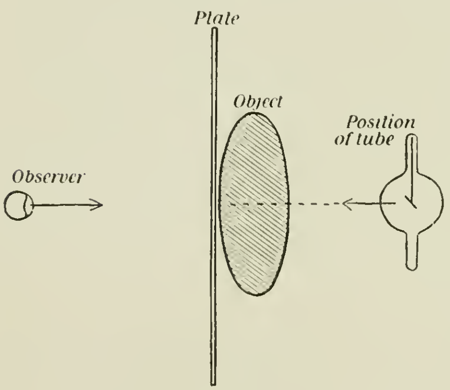
The negatives should be on a level with the eyes and, if possible, slightly tilted towards each other.

By concentrating the attention through the plain tube (*i.e.* the one without the prism) and centering the image on the corresponding side, a stereoscopic effect is at once perceived even by those who are unaccustomed to stereoscopic work.

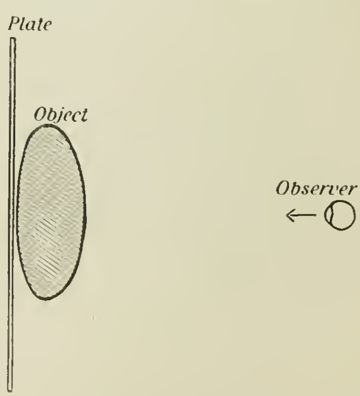
The correct position of the foreign body may be located and a statement made as to its position relative to well-known landmarks, but when operation for removal is contemplated the surgeon should examine the plates on the stereoscope and form a mental picture of the position of the foreign body which should guide him throughout the operation. To facilitate this a stereoscope should be placed in close proximity to the operating theatre.

The plates are developed, fixed, washed, and dried; if time is of importance they may be rapidly dried or may even be examined wet. The latter process is not to be recommended as the film is apt to melt when exposed to the heat given off from the lamps behind.

We now have two plates representing the part taken from two points of view. The distance from the anti-cathode of the X-ray tube to the surface of the plate is measured. The distance from the plate when placed in the stereoscope to the surface of the mirror should be approximately the same as that from the plate to the anti-cathode. The plate marked "left shift" is placed on the left side, that marked "right shift" to the right; the film side of the plate is outwards.

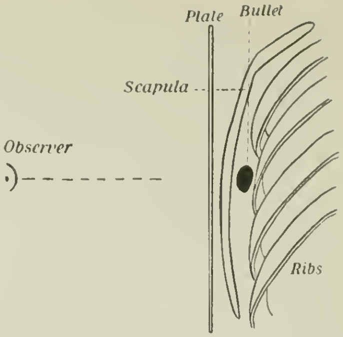


The mirrors of the stereoscope are now adjusted, by moving the upright upon which they are placed backwards and forwards, to suit the accommodation of the observer, and observations are made. The eyes now view the radiographs as one image in stereoscopic relief—(for explanation see Fig. 121)—looking at the picture as seen from the far side of the object. The observer looks through the object from a point of view opposite to that of the tube.



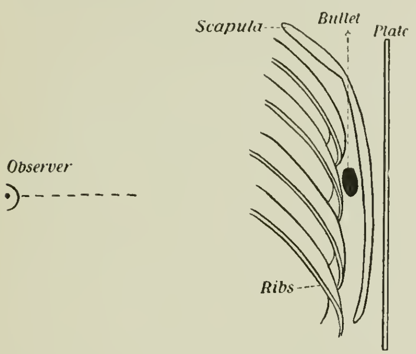
Careful adjustments enable us to see the object, the foreign body, and its relationship to structures in its neighbourhood. The plates are next reversed so that now the glass side of the plate is outwards, facing the mirror. The position is therefore reversed; the observer looks into the plate through the object, from the point of view of the tube.

The examination of the radiogram in these two positions gives us the information we require, because in correct stereoscopic relief the objects are shown in their true relationship to one another. The process of viewing and localising a foreign body in relation to anatomical structures will best be understood if we take an example of a foreign body in a patient. For this purpose it will be well to describe by diagrams (taken from radiograms) an example of a rifle bullet in a patient's shoulder region.



Negatives of the shoulder-joint, taken in the manner described, are placed in the stereoscope, with the film side of the negative outwards facing the mirror. The picture presented is seen as in diagram.

In position two, by changing the plates so that the glass side is outwards, the relationship of the parts is reversed.



The observer notes that the ribs appear nearest to the eyes, then comes the bullet, and behind it the scapula.

The inspection of the radiograms from these two points of view clearly indicates that the bullet lies between the ribs and the scapula. The depth may be determined by the triangulation method of measurement or by one of the more rapid methods.

Having shown that the foreign body has a definite position in relation to well-known anatomical landmarks, its depth is readily ascertained by measurements, and the surgeon now has very definite facts to go upon.

In any particular instance it is possible to demonstrate clearly the position of a foreign body by taking other plates with the arm in different positions; if the foreign body moves in these it must be outside the thorax and embedded in bone or muscle.

The plate may be placed upon the upper aspect of the shoulder and the tube centred upon the axilla; Fig. 125 shows a radiogram from a case taken in this position.

Fig. 125.—Radiogram of shoulder.

Taken with the plate placed above the shoulder-joint, with the tube centred in the axilla. A fracture of the humerus is shown, but the bullet is just outside the range of the plate. See Fig. 126.

Or a small plate may be placed in the axilla; the arm being abducted to its fullest extent, the tube is centred from above upon the centre of the joint; Fig. 126 shows a shoulder-joint taken in this position with a bullet lying in relation to the scapula.

Fig. 126.—Radiogram of same shoulder as in Fig. 125, taken with plate in the axilla, and the tube centred above the joint.

This shows a fracture of the upper shaft of the humerus, and a rifle bullet in relation to the body of the scapula and the acromion process.

Additional plates may be taken to show the movements of the foreign body with the scapula.

The changing view of the objects on the plate with the change of the position of the plates is somewhat difficult to understand. It, however, becomes clear when we remember that we are looking through the body of the patient and not at it as we do when viewing ordinary photographic prints instead of the radiographic stereoscopic plates, so that if we view the body as seen on the radiograph we look through it from whichever point of view we take.

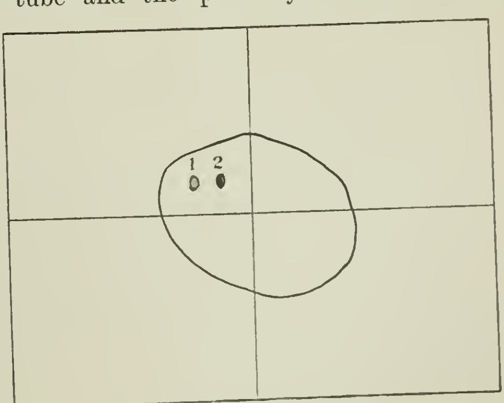
In the first position described, the observer is looking towards the tube through the glass of the negative, then through the film on which the impression of the body is made; in the stereoscope this gives the form of the bony structures of the body in relief. The actual structures composing the picture are made up of layers of tissue and skin, muscle, bone, muscle, bone, then contents of the thorax, and again bone, muscle, skin; the objects nearest to the plate are sharp in outline, those further removed throw a corresponding larger and less sharp outline. It is easy now to see

Fig. 127.—Radiogram of same shoulder as above, taken with the plate behind the shoulder and the tube in front. Showing rifle bullet.

the correct relative positions of the parts; in position two the observer is now looking at the object from the point at which the tube is situated, consequently the structures nearer to the observer, in this particular instance the anterior ribs, are in relief, the posterior portions of the ribs are nearer than the foreign body; they therefore appear in front of the bullet, then behind it is the scapula, and if cross wires have been used they also appear behind all the structures. It is customary in some cases to place a known body, *i.e.* a piece of lead or a metal figure, on a point of the skin (for convenience the entrance wound is utilised if it is anywhere near the bullet); the shadow thrown by the known body is useful as a guide and may subsequently be used for measurements. This plan is followed in the localisation of foreign bodies in the orbit or eyeball when using Mackenzie Davidson's cross-thread localisation method.

The stereoscopic method has the great advantage possessed by all plate methods, namely, the securing of a permanent record of the foreign body and its position in the patient. This enables us at any time to produce the plates and demonstrate the position of the foreign body. It is, therefore, only another step to place in or near the operating-room a form of stereoscope which will enable the surgeon to inspect the radiograms prior to or even during the course of the operation. A stereoscope may be adjusted if desired close to the operating table.

As to the necessary apparatus for taking stereoscopic radiographs, if only those parts of the body which can be kept stationary without effort are required, and time is not an important factor, then an ordinary stereoscopic plate-holder can be used where the patient lies upon a holder with a top which is transparent to the X-rays. Into this holder two plates are placed, which can be exchanged without moving the patient. On the other hand, if stereoscopic records of those parts of the body which cannot be controlled voluntarily are required, then an automatic arrangement must be adopted to shift the tube and the plate synchronously and instantaneously. There are already several of these devices on the market, but they are daily being improved, and we shall no doubt shortly have a perfect one produced.



1 and 2. Shadows of foreign body.

The method described may be combined with the cross-thread localiser of Mackenzie Davidson for the *exact localisation of the foreign body* by measurements made from the plates. In order to do this it is necessary to place upon the plate cross wires which will make an impression upon the skin of the patient, and this can be at once rendered more or less permanent by marking in copying ink, or a preparation of aniline, gentian, violet, or silver nitrate may be used. The cross wires make a permanent record upon the photographic plates.

The two negatives are superimposed so that the impression of cross wires on the one is exactly in position over the impression on the other. The picture now shown consists of (*a*) cross wires, (*b*) object on plate, (*c*) foreign body.

There are now two shadows of the foreign body seen on the picture; the distance between the two is an indication of the change induced by moving the X-ray tube.

The method of production can best be explained by a diagram.

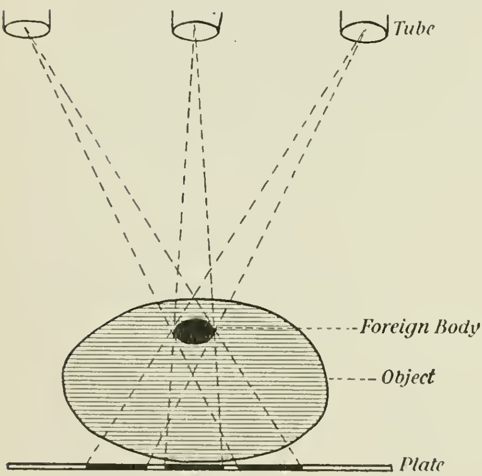


Fig. 128.—Projection of rays upon a plate with the tube above the patient.

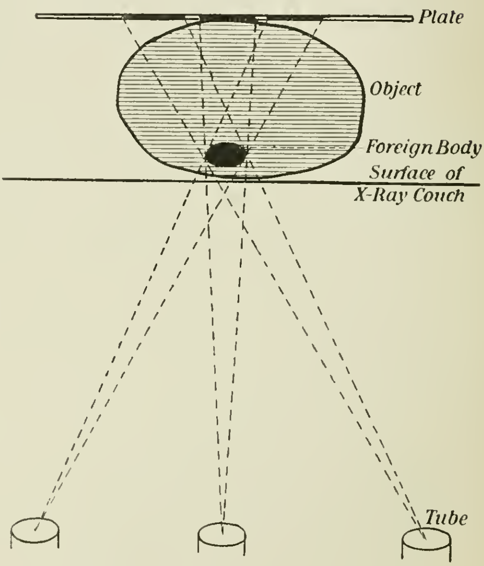


Fig. 129.—Projection of rays upon a plate with the tube beneath the patient.

Showing the change in position with a given movement of the tube. The direct vertical position is also shown in this diagram.

To calculate the depth of the foreign body from the surface of the patient's skin near to the plate the following procedure is followed.

The T-shaped piece of the localiser (see Fig. 130) is adjusted to correspond to the distance between the anti-cathode of the tube and the X-ray plate; for convenience in general work a distance of 50 centimetres is chosen and a predetermined displacement of the tube used. This is the method adopted by Hampson and others for the rapid localisation of a foreign body.

The cross threads are arranged on needle points and the following measurements made: A corresponding point on the two shadows is selected, the needle points are placed on these so that the threads cross in space (the threads then represent the path of the centred rays in the two positions of the tube)—the point of intersection is taken and the distance from it to the surface of the plate is measured. The marks on the skin corresponding to the cross wires on the plates are utilised for the purpose of indicating the exact position of the foreign body.

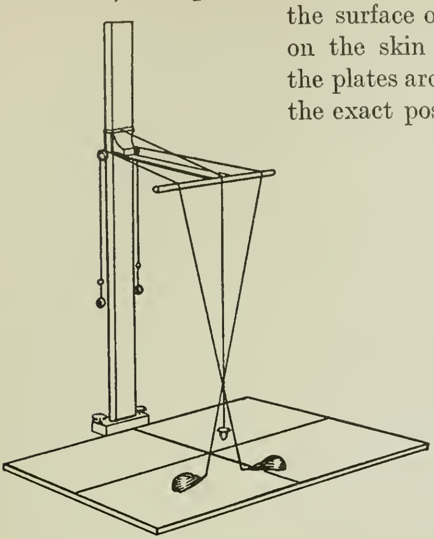
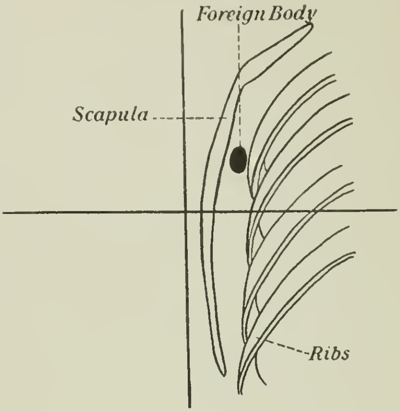


FIG. 130.—Diagram to illustrate the method of using the cross-thread localiser.

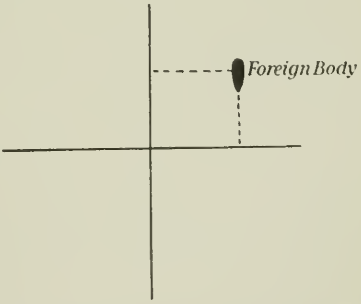


In actual practice it is advisable to get the shadow of the foreign body near to the centre of the cross wires.

When the exact position of the foreign body has, by the triangulation method, been worked out, it is possible to state three measurements in relation to the cross wires :

(1) The depth, (2) the distance from the vertical line, (3) the distance from the horizontal line, and the section of the plate defined by the shadow of the cross wires.

It is now possible to use the marks which have been made on the skin surface, and by exact measurements arrive at a spot beneath which the foreign body lies. A mark should be made on the skin at this point.

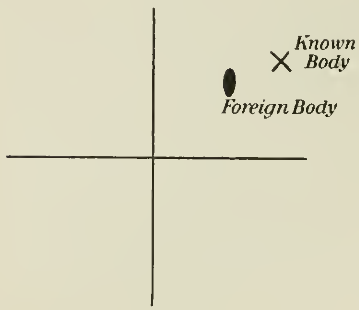


Depth 3 centimetres at a point situated $1\frac{3}{4}$ cm. from the vertical line, and $1\frac{1}{2}$ cm. from the horizontal line. The foreign body lies in these dimensions of space at a point beneath the mark on the skin surface.

A record of this may be made in the form of a drawing on a report sheet. The glass side of the plate is used and the paper corresponds to this surface, which gives the position of the foreign body as the surgeon looks at it when operating.

A more convenient way is to dispense with the cross wires or only to use them when necessary and to use a known body on the surface of the skin ; measurements can then be made from the known body to the foreign body, as in diagram on page 158.

This modification is added to the triangulation method when localising foreign bodies in the eye or orbit and the point marked represents the depth from the surface at which the foreign body lies.



In actual practice the usual procedure to follow is to accurately localise the foreign body, take stereoscopic plates and mark the skin. Just prior to the operation the patient should be screened, and a spot marked as a guide to the surgeon. In difficult cases it is impossible to take too great care in the localisation.

When the surgeon uses the stereoscopic method for the information necessary, this is the only measurement it is essential to give, because he has made a mental picture of the position and relations of the foreign body; the depth is not quite so easy to ascertain by the stereoscopic method alone. It is therefore quite a convenient and reliable method to employ the cross-thread localiser for the measurement of the depth and the stereoscopic view for the position only. The surgeon must, however, examine the plates in the stereoscope. The depth may be measured more rapidly by Hampson's method.

Stereoscopic fluoroscopy has also been attempted, but although possible and indeed successful with parts of the body such as the hand and the foot, this has hardly been satisfactory with the thicker parts.

Sir James Mackenzie Davidson many years ago called attention to the possibility of stereoscopic fluoroscopy. Pirie has also described an instrument used in conjunction with a Snook machine which gave good results. Dessauer has more recently produced an apparatus which gave satisfactory screen pictures.

A properly constructed and efficiently protected apparatus would be of great service in connection with war work, for the removal of foreign bodies.

THE LOCALISATION OF FOREIGN BODIES

The demonstration of a foreign object in any part of the body is one of the most useful functions of the X-ray examination, and its accurate localisation is one of the most difficult duties of the radiographer. Even after a body has been definitely localised, the surgeon may not be able to measure exactly the distances from given points so as to make his incisions and extract the foreign body at once. There are fallacies in the interpretation and miscalculations of distance, and, lastly, it must not be forgotten that if a foreign body is located, the patient must be placed in exactly the same position at the time of operation as he occupied when the radiographs were taken. A slight degree of flexion or rotation of a limb will upset the calculations, and the foreign body may be found to be as much as 1 or 2 inches away from the spot at which it had been localised. It must also be pointed out that if a localisation is to be of its greatest value it should be done immediately before the surgeon operates; if possible it should be done in the operating theatre. Where many cases require investigation a small theatre should be attached to the X-ray department. Of the various methods for localising foreign bodies the most useful and probably the best known is that introduced by Mackenzie Davidson. The details of the method will be dealt with later. Modifications of this method exist, and have been used by many workers. Foreign bodies are met with in all parts of the body, and the localisation will vary in difficulty according to the part in which a foreign body is found. In the limbs they are comparatively easy of localisation, but in the skull, thorax, and abdomen the greatest difficulty may be experienced.

Probably the best all-round method of localisation in the latter regions is the stereoscopic. This is carried out in the same way as in ordinary stereoscopic work. Two plates are necessary, and in most cases it will be found useful to place on the skin of the patient an opaque body which will give a shadow, and may be used as a landmark for subsequent comparison. By employing cross wires the stereoscopic may be used in conjunction with Mackenzie Davidson's method. Stereoscopic plates should be developed together in order to secure, if possible, the same density of negative; similarly the condition of the tube and length of exposure should be the same for each plate. A note should be made of the position of the plate in relation to the body of the patient. This will be found useful when it is necessary to state the exact position of the foreign body in relation to fixed anatomical landmarks.

Simple Methods of Localisation.—There are simpler methods for localisation which may be employed in cases which are not likely to require an exact degree of measurement. Foreign bodies in the limbs come under this heading. It is obvious that in some instances one negative is sufficient to indicate the position of the foreign body, though it is surprising how difficult an apparently easy case may become under some circumstances. All operations for removal should be undertaken as soon as possible after the radiograph. Difficult cases require more elaboration, and in all instances of bodies in the limbs two radiographs should be taken: (1) antero-

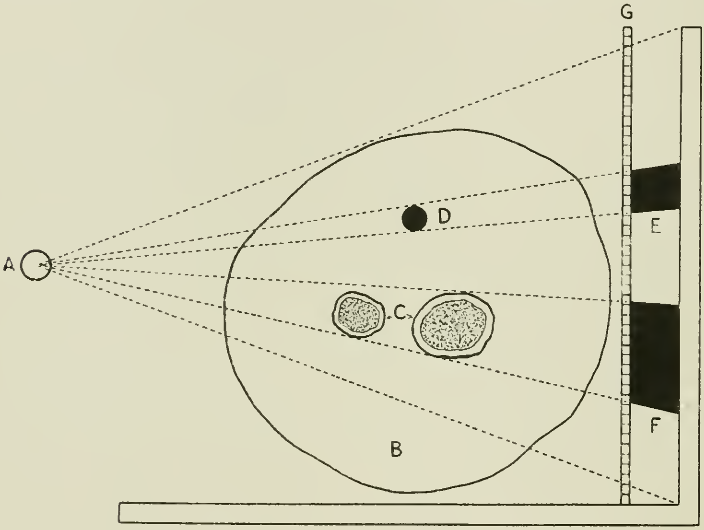


Fig. 131.—Diagram to show method of taking a lateral view.

A, Source of X-rays.
D, Foreign body.
C, Bones.
B, Limb.
E, Shadow of foreign body on plate.
F, Shadow of bones.
G, Graduated scale.

posterior position, (2) lateral position. The limb need not be moved when these exposures are made. A simple plate-holder with a second one at right angles will suffice. The tube alone requires to be moved. An examination of the two negatives should give the position of the foreign body. In the plate taken in position (1), the distance from a given point, probably a bony landmark, is taken. The plate taken in position (2) shows the depth from the surface. In most instances this should be sufficient, as the operator has only to measure the distance and make a mental note of the position.

In order to get a graphic record of the measurements, a simple plate-holder can be constructed with an inch or centimetre rule, which slides over the surface of the plate so that it may be placed in relation to a bone or foreign body. A second inch or centimetre scale runs at right angles to the longitudinal one. The marks on the scale are rendered opaque by inserting pieces of wire into the wood at the correct distances. The second plate-holder is fixed at right angles to the first one and also has sliding scales. The foreign body may be located by screening prior to the taking of the plates. When the two negatives are examined it is easy to locate the foreign body with the assistance of the shadows thrown by the sliding scales. For exact localisation the Mackenzie Davidson method should be employed.

Method employed in Mackenzie Davidson Localisation.—The central ray emitted from an X-ray tube has to be definitely found. To do this it is necessary to have an arrangement for determining the central ray.[1] The tube is accurately fixed in the box beneath the table ; the latter moves in two directions on trolley wheels. The central ray is located by means of cross wires, or by a plumb-line running on pulleys and moving with the tube, so that whatever the position of the tube the plumb-line always indicates the position of the focus of rays upon the anti-cathode. The distance of the anode from the top of the couch is constant, and should be recorded on a convenient place on the couch ; the distance of the plate from the top of the couch must also be taken into consideration. The two added together give the distance of the anode from the plate. When working with the tube above the patient, the two positions of the anode are secured by moving the tube along a horizontal bar which is marked with a millimetre scale, running both ways from a central point at zero. The sensitive plate is placed underneath the patient, and protected in the usual way by black paper, or it may be placed in a light-tight cassette. Two wires are laid at right angles to each other on the photographic envelope, and so placed that one of them runs in the same direction as the horizontal bar which carries the tube above, and their point of intersection lies beneath zero on the scale. The cross wires may be fastened to a thin board or sheet of vulcanite, and retained in position over the sensitive plate by drawing-pins, or they may be permanently fixed to a frame, upon which the plate is placed. The marks corresponding to the cross

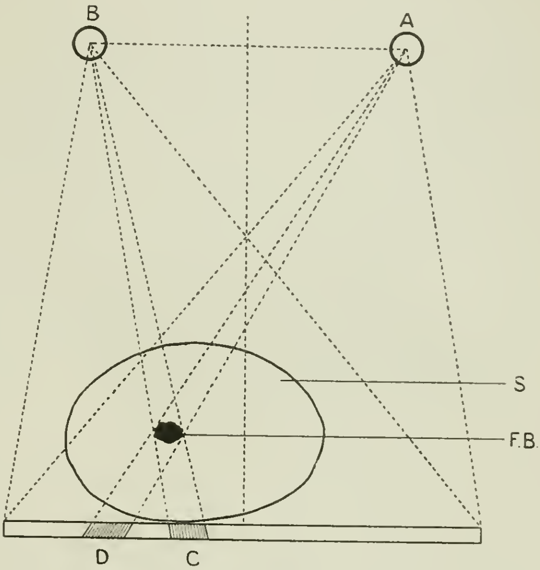


Fig. 132.—Diagram showing Mackenzie Davidson method. (After Walsh.)

A, First position of tube.
B, Second position of tube.
S, Skull or limb.
F B, Foreign body.
D, Shadow thrown on plate by tube in A position.
C, Shadow thrown on plate by tube in B position.
Dotted lines represent the paths of the rays.

[1] The term "central ray" is somewhat misleading. It is obvious that no particular ray can be exclusively employed. The term may be taken to signify the bundle of rays emerging from the centre of the focus spot upon the anti-cathode.

wires should be painted with aniline ink or silver nitrate solution, so as to leave a mark on the body of the patient. In actual practice, if the cross wires are thick enough to leave an impression upon the skin, the marking can be rendered permanent by painting the lines on the skin immediately the patient rises from the table ; it is convenient to identify one of the corners of the plate by some opaque object, such as a small coin, with a corresponding sign on the adjacent skin surface. Two equidistant points are marked off by clips, or any other method, at each side of zero on the horizontal scale bar, at a distance decided on by the operator. The focus-tube is drawn up to one side-clip, and an exposure made. It is then pushed over to the other clip, and a second exposure made of equal length. The distance from the centre point of the anode to the plate is then carefully measured. Accurate data have now been obtained, from which the operator may calculate the exact relation of a foreign body in the tissues to the aniline cross mark on the patient's skin.

When the tube is operated from below a similar arrangement is used, the tube being first centred over a known point of the part to be radiographed. A scale is attached to a convenient part of the table and the movement to one side (a known distance, say 3 cm.) is made. The tube-box is fixed and the exposure is then made. The plate is removed and a second one placed in exactly the same position. The tube is now moved 6 cm. in the opposite direction to the first movement, and the second exposure is made. It should be noted that the frame with the cross wires and the plates occupies the same position relative to the patient during the two exposures. It is also possible to make the two exposures on one plate by exposing only half at a time, thus enabling a little time to be saved in the subsequent procedures for localisation.

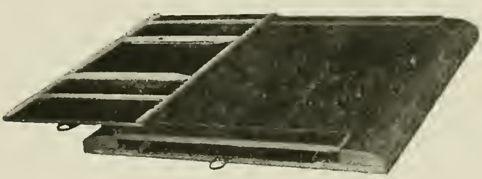


Fig. 133.—Gouldesbrough's plate-holder, with displaceable centre. (A. E. Dean.)
This can also be used for stereoscopic work.

Having obtained the radiographic records we next proceed to the exact localisation of the foreign body. This is done by means of the cross-thread localiser (Mackenzie Davidson). The apparatus consists of an adjustable horizontal bar, which is marked with a millimetre scale starting from a central zero, and is notched to correspond on its upper edge ; a plate-glass stage marked with two lines at right angles to each other, the point of intersection lying exactly beneath zero on the horizontal bar. Beneath the stage is a hinged reflecting mirror. The developed negative or tracings of the two plates on a celluloid sheet is placed film upwards on the glass stage, and the shadow of the wires made to correspond with the cross mark on the stage. The bar is next raised or lowered so as to bring the zero of the scale to the same distance from the scale as that of the centre of the anode from the sensitive plate when the exposures were made. Two fine silk threads are next passed over the horizontal scale bar. Each thread has a weight at one end to keep it taut, and is fixed in a notch on the scale corresponding to the distance of the anode from zero during the original exposure. The other end is threaded into a fine needle fixed in a piece of lead. The path of the thread between the notch on the scale and the eye of the needle represents the path of the X-ray and is movable. A second thread is passed through the notch at the other end of the horizontal bar. It represents the path of the rays during the second exposure after the tube has been moved.

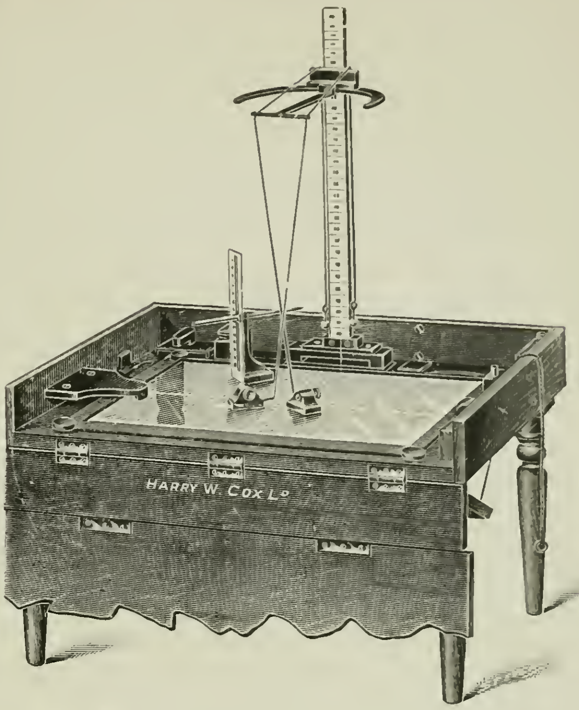


Fig. 134.—Mackenzie Davidson cross-thread localiser. (Cox & Co.)

With two such threads, then, it will be easy to trace the path of the rays in relation to a body interposed between the focus-tube and the sensitive plate. One threaded needle is placed upon any particular part of one of the photographic shadows of the foreign body, and the other needle upon a corresponding part in the second shadow. The point where the threads cross and touch each other will represent the position of the part of the foreign body chosen for location. A perpendicular is then dropped from the intersection of the threads to the negative below, and a mark made where the perpendicular touches the negative. The distance of the spot thus marked out from the cross wires is measured by a pair of compasses. The operator is now in possession of the required measurements. If the distances are 3 cm. and 1 cm., and the depth from the crossing of the threads to the plate $2\frac{1}{2}$ cm., then he knows that the foreign body lies at $2\frac{1}{2}$ cm. from the surface of the patient's

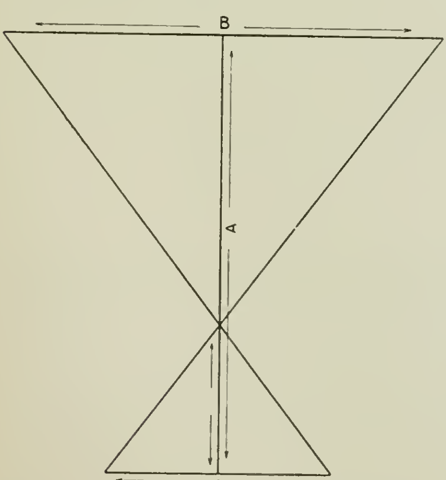


Fig. 135.—Diagram to illustrate simple formula for localising. (After Walsh.)

skin, at a distance of 3 cm. and 1 cm. from the cross wires, in a quadrant that is easily determined by reference to the distinguishing mark placed there when taking the double-exposure radiograph.

Dawson Turner and others have published a simple formula for localising. Two radiographs are taken on one plate by moving the tube a known distance. The distances are measured from tube to plate (A), between the two positions of the tube (B), and between the two shadows on the photographic plate (C). Let x equal the distance of the foreign body from the plate.

Then $$x = \frac{a \times c}{b + c}.$$

Supposing a to be 33 cm., b 10 cm., and c 1 cm., then

$$x = \frac{33 \times 1}{10 + 1} = 3 \text{ cm.}$$

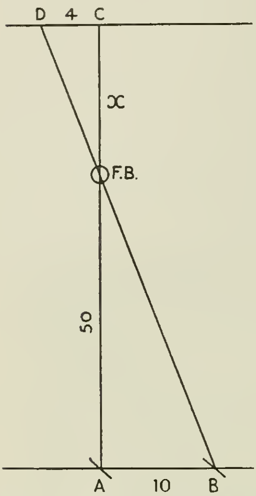


Fig. 136.—To illustrate Mackenzie Davidson's short method of localisation.

$4 : x :: 10 : 50 - x.$

F B, Foreign body.
A, First position of tube.
B, Second position of tube.
C, Position of image of F B in first position. A mark is made on the skin at this spot.
D, Shadow of F B in second position of tube.

Mackenzie Davidson has suggested a short method of localisation which, while based on his original method, allows of more rapid localisation. The central ray is determined and the position fixed by means of a plumb line. The foreign body is located directly under the point of the plumb line. A mark is made upon the skin, a plate is exposed, the tube is moved a known distance, and a second exposure made. The depth of the body is determined by calculation in the ordinary way. Two cross wires, arranged at right angles, must be used. Dr. Hampson has simplified this method still further by having a graduated scale fixed to the fluorescent screen.

Hampson's Method of Localisation.—The method introduced by Dr. Hampson is briefly as follows :

Place the patient on the couch and arrange the tube in the tube-box with the focus point at a determinate distance, say 50 cm., beneath the surface of the screen. Contract the diaphragm opening so as to make it easy to centre the foreign body in the field of view. The rays through it will be practically vertical, and a small arrow head or other metallic mark fixed on the skin will localise the selected point of the foreign body in two dimensions, along and across the trunk or limb. For the estimation of the depth a

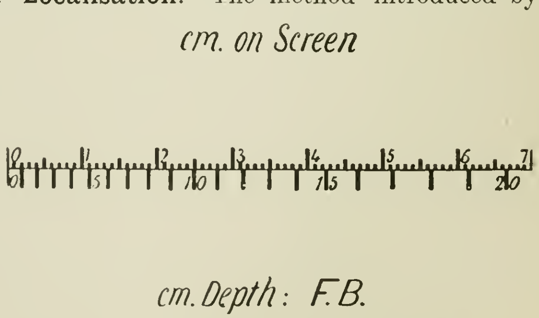


Fig. 137.—Graduated scale in Hampson localiser.

mark is placed on the glass of the screen over a selected point of the foreign body. Move the tube-box, and with it the focus, a known distance, say 10 cm., and mark on the glass the new situation of the selected point, opening the diaphragm wider if necessary. Measure the distance that the shadow of the point has travelled, read this off on the upper side of the scale (Fig. 137), and the corresponding number on the lower scale will be the depth of the foreign body beneath the screen. If the part of the patient under examination is concave and does not touch the screen, this must be allowed for in stating the depth.

In cases where the distance between the screen and focus point cannot be permanently adjusted, the same result can be obtained with very little trouble and delay. Ascertain by measurement what the distance is, mark the *traverse* of the shadow as before, and then work out the result as follows: AB (Fig. 138) is a line equal to the vertical height from screen to focus. AC is the horizontal movement of the focus. BD is the horizontal movement of the shadow on the screen.

Draw a line DC intersecting AB in E. Then BE is the depth of the foreign body below the screen.

The correctness of the result depends on the accuracy of the measurements, so these should be made as few as possible in order to reduce the occasions for inaccuracy. It is, therefore, better to measure directly the distance from focus level to screen by means of a large pair of callipers.

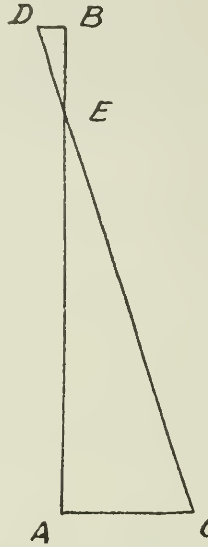


Fig. 138.—Hampson localiser. Diagram to illustrate method.

Other distances than 50 cm. may be used, but a separate scale must be prepared for each distance. A table prepared for the 50 cm. interval will be found useful: *e.g.*

½	cm. traverse on screen	means	a depth of	2½	cm.
1	,,	,,	,,	4½	,,
2	,,	,,	,,	8⅓	,,
3	,,	,,	,,	11½	,,
4	,,	,,	,,	14⅓	,,

Thurstan Holland has adopted the method of Hampson; he uses an Ironside Bruce couch and has fitted to it a simple device for automatically changing the position of the tube between the two exposures, and has further, on the suggestion of Dr. Oram,[1] added to the couch a simple and accurate means of measuring the distance between the anti-cathode of the tube and the surface of the screen. He has also compiled charts which enable one to read off quickly the depth of the foreign body (see tables facing page 166).

Holland has also introduced an improvement in the screen method

[1] The method is fully described by Dr. Oram in a paper published in the *Archives of Radiology and Electrotherapy*, February 1917.

used for rapid localisation; a small screen is used which has a wide margin of lead rubber around its edges, which serves as a protection for the operator. The screen is covered by a piece of lead glass and in the centre of this is a small hole. The hole is accurately centred over the shadow of the foreign body, and the skin is marked by ink or an indelible lead pencil; this marks the first position of the shadow. The tube is moved 10 cm. in one direction, and a graduated scale fitted to the screen gives the depth of the foreign body, which is calculated by the distance between the shadows.

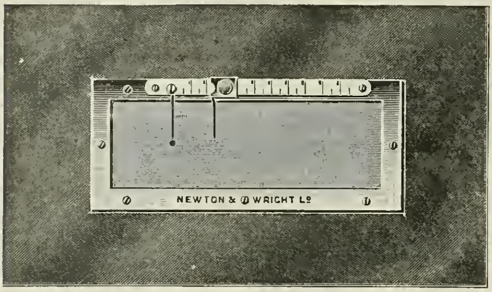


FIG. 139.—Localising screen. (Thurstan Holland.)

For the rapid localisation of a foreign body Herneman Johnson advocates a "ring localiser." He uses a metal ring attached to a long flat wooden handle; the long handle ensures the operator a measure of protection by keeping his hands well out of the range of the X-rays. The patient is screened (the tube being beneath the table, the screen above the patient), the ring is slipped under the screen, the bullet shadow is centred in the ring, and an automatic skin marker attached to the ring marks the point on the

FIG. 140.—Ring localiser.

skin beneath which the body lies. The ring is next slipped under the patient, the foreign body is again centred in the ring, and the skin is marked on the under surface of the patient; the foreign body lies between the two marks in a line joining them. If a limb is under examination it is next rotated to a right-angled position and the marking is repeated on the two lateral aspects of the limb. The depth of the foreign body is calculated by the triangulation method. This method is a useful one, but it is necessary to exercise great care in the movement of the limb if accuracy in localisation is expected.

Jordan advocates the use of the method of parallax. This method has been fully described by Shenton in several papers; it has been used by several workers and is undoubtedly a reliable method.

Shenton's Method of Localisation.—Shenton relies chiefly on the screen method of examination and denounces all radiographic methods. He uses a circular diaphragm of small diameter and centres this accurately under the foreign body. A metallic pointer or probe is now passed between the screen and the limb under investigation, and its tip placed over the shadow of the foreign body, or to be more correct, the shadow of the probe is watched until it coincides with the shadow of the bullet, the probe is held steadily in position, the room is lighted up, and the exact position of the probe point is marked upon the skin surface. This is a point immediately over the bullet, and it is manifest that an incision carried to a correct depth must find the object sought for. It remains therefore to ascertain the exact depth at which this lies. A straight probe is used. Around it is twisted a piece of lead foil or soft wire so as to make an appreciable bulge. Turn the limb upon its side, *i.e.* at right angles to its former position; then place the tip of the prepared probe on the spot marked upon the skin, letting the probe lie horizontal to it, or in other words, parallel with the screen. Next slide the piece of lead foil along the probe until its distance is equal to that of the point from the bullet or other foreign body. The distance between the point of the probe in contact with the skin and the bulge caused by the lead foil is equal to the distance between the skin surface and the position of the bullet. The distance may be measured upon the probe, and the operator is in a position to say that the bullet lies under the spot already marked upon the skin, and that the depth corresponds to a known distance as measured by the probe and the movable bulge upon it.

Shenton has introduced a localiser which he says is really a depth-gauge. This is a very ingenious and useful apparatus for localising foreign bodies in the limbs.

Captain Harold Gamlen has described a rapid localiser which has

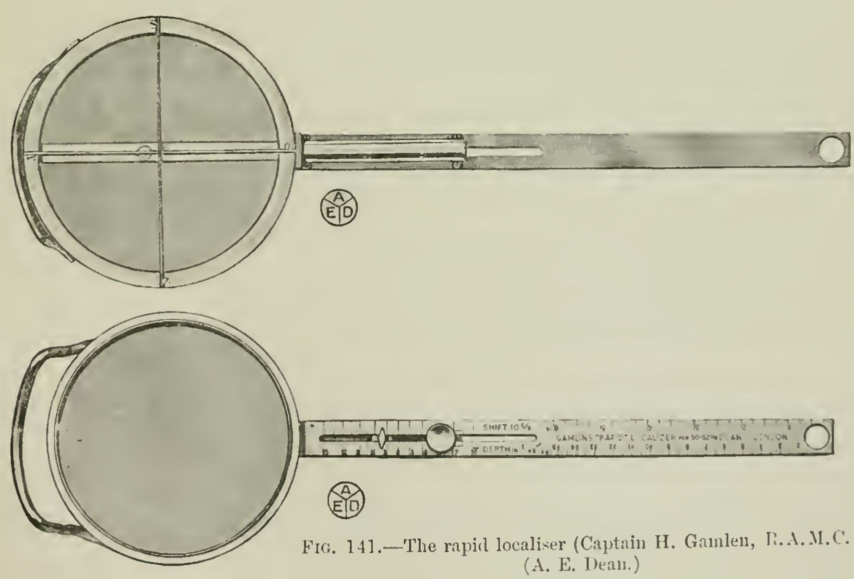


Fig. 141.—The rapid localiser (Captain H. Gamlen, R.A.M.C.). (A. E. Dean.)

several advantages over others of a similar nature. The instrument is a localising pressure screen; it is made in three sizes, 2, 4, and 6 inches in diameter; the smallest will fit into any part of the body, and the largest is useful for any ordinary screen examination. When used with a thoroughly protected X-ray couch this screen can be safely recommended for screen examination and rapid localisation.

The essential parts of the apparatus are :

(1) Fluorescent screen.
(2) Localising apparatus.
(3) Cross-thread marker.

The fluorescent screen is circular in shape and has in front of it a piece of lead glass ; the under surface of the screen has in apposition with it a piece of aluminium.

Beneath this are cross strips of metal at right angles to each other ; the one in line with the handle is aluminium, the other consists of a thin piece of steel.

Beneath the handle is a thin, narrow aluminium movable rod, one end of which terminates halfway up the handle in a pointer and finger button to allow of ready movement of the rod. At the free end of the rod a small lead shot is fixed ; the normal situation of this is at the centre of the cross strips. When the shot is moved it records the depth of the foreign body on a graduated scale on the handle.

The instrument is graduated for a distance of 52 cm. between the anti-cathode and the plate, and for a tube displacement of 6-10 cm. The position of the part to be radiographed or screened is always adjusted to these distances by means of air cushions placed beneath the part.

The procedure of operation is as follows :

The part to be examined is placed in position and screened for the location of the foreign body, and the limb is then placed in the position most suitable for operation ; now close down the diaphragm of the X-ray box until the fluorescence just covers the screen. The screen, with the lead shot at the central point, is moved until it overlaps the foreign body or a portion of it, and is firmly pressed upon the part. The diaphragm is then shut down until only a narrow beam of light is seen and the tube is moved to the second position. The lead shot is now moved until it is adjusted over the foreign body, and the movement of the shot is recorded on the scale. The depth at which the foreign body lies may now be read on the scale. The impress of the cross bars is readily seen on the skin of the patient, and may be rendered permanent by marking with aniline, gentian, violet, or other stain.

The round hole at the free extremity of the handle, which has a raised edge, may be used to mark the direction of the pencil of rays indicating the line in which the foreign body lies by placing the handle beneath the patient until the hole appears in alignment with the foreign body, and when this has been ascertained a mark is made on the skin by pressing the handle gently upwards. This can be rendered permanent by using a stain or a copying-ink pencil.

In addition to the methods of the combined use of the screen and plate there are several which enable us to dispense with the screen and work with the plate alone. These are :

(1) The stereoscopic.
(2) Method recommended by Blake.
(3) Harvey's localising cassette, Shaxby's ladder, and others.

Distances between the Anti-Cathode and Screen, in Centimeters.

Distances of Displacement of Shadow of Foreign Body	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	Fraction to be added or subtracted for each Centimeter of distance more or less.
½	2 8/21	2 7/21	2 6/21	2 5/21	2 4/21	2 3/21	2 2/21	2 1/21	2	1 20/21	1 19/21	1 18/21	1 17/21	1 16/21	1 15/21	1 14/21	1 13/21	1 12/21	1 11/21	1 10/21	1/21
1	4 6/11	4 5/11	4 4/11	4 3/11	4 2/11	4 1/11	4	3 10/11	3 9/11	3 8/11	3 7/11	3 6/11	3 5/11	3 4/11	3 3/11	3 2/11	3 1/11	3	2 10/11	2 9/11	1/11
1½	6 12/23	6 9/23	6 6/23	6 3/23	6	5 20/23	5 17/23	5 14/23	5 11/23	5 8/23	5 5/23	5 2/23	4 22/23	4 19/23	4 16/23	4 13/23	4 10/23	4 7/23	4 4/23	4 1/23	3/23
2	8 4/12	8 2/12	8	7 10/12	7 8/12	7 6/12	7 4/12	7 2/12	7	6 10/12	6 8/12	6 6/12	6 4/12	6 2/12	6	5 10/12	5 8/12	5 6/12	5 4/12	5 2/12	2/12
2½	10	9 20/25	9 15/25	9 10/25	9 5/25	9	8 20/25	8 15/25	8 10/25	8 5/25	8	7 20/25	7 15/25	7 10/25	7 5/25	7	6 20/25	6 15/25	6 10/25	6 5/25	5/25
3	11 7/13	11 4/13	11 1/13	10 11/13	10 8/13	10 5/13	10 2/13	9 12/13	9 9/13	9 6/13	9 3/13	9	8 10/13	8 7/13	8 4/13	8 1/13	7 11/13	7 8/13	7 5/13	7 2/13	3/13
3½	12 26/27	12 19/27	12 12/27	12 5/27	11 25/27	11 18/27	11 11/27	11 4/27	10 24/27	10 12/27	10 10/27	10 3/27	9 23/27	9 16/27	9 9/27	9 2/27	8 22/27	8 15/27	8 8/27	8 1/27	7/27
4	14 4/14	14	13 10/14	13 6/14	13 2/14	12 12/14	12 8/14	12 4/14	12	11 10/14	11 6/14	11 2/14	10 12/14	10 8/14	10 4/14	10	9 10/14	9 6/14	9 2/14	8 12/14	4/14
4½	15 15/29	15 6/29	14 26/29	14 17/29	14 8/29	13 28/29	13 19/29	13 10/29	13 1/29	12 21/29	12 12/29	12 3/29	11 23/29	11 14/29	11 5/29	10 25/29	10 16/29	10 7/29	9 27/29	9 18/29	9/29
5	16 10/15	16 5/15	16	15 10/15	15 5/15	15	14 10/15	14 5/15	14	13 10/15	13 5/15	13	12 10/15	12 5/15	12	11 10/15	11 5/15	11	10 10/15	10 5/15	5/15

Distances between the Anti-Cathode and Screen, in Centimeters.

Distances of Displacement of Shadow of Foreign Body.	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	Fraction to be added or subtracted for each Centimeter of distance more or less.
¼	1 9/41	1 8/41	1 7/41	1 6/41	1 5/41	1 4/41	1 3/41	1 2/41	1 1/41	1	40/41	39/41	38/41	37/41	36/41	35/41	34/41	33/41	32/41	31/41	1/41
¾	3 21/43	3 18/43	3 15/43	3 12/43	3 9/43	3 6/43	3 3/43	3	2 40/43	2 37/43	2 34/43	2 31/43	2 28/43	2 25/43	2 22/43	2 19/43	2 16/43	2 13/43	2 10/43	2 7/43	3/43
1¼	5 25/45	5 20/45	5 15/45	5 10/45	5 5/45	5	4 40/45	4 35/45	4 30/45	4 25/45	4 20/45	4 15/45	4 10/45	4 5/45	4	3 40/45	3 35/45	3 30/45	3 25/45	3 20/45	5/45
1¾	7 21/47	7 14/47	7 7/47	7	6 40/47	6 33/47	6 26/47	6 19/47	6 12/47	6 5/47	5 45/47	5 38/47	5 31/47	5 24/47	5 17/47	5 10/47	5 3/47	4 43/47	4 36/47	4 29/47	7/47
2¼	9 9/49	9	8 40/49	8 31/49	8 22/49	8 13/49	8 4/49	7 44/49	7 35/49	7 26/49	7 17/49	7 8/49	6 48/49	6 39/49	6 30/49	6 21/49	6 12/49	6 3/49	5 43/49	5 34/49	9/49
2¾	10 40/51	10 29/51	10 18/51	10 7/51	9 47/51	9 36/51	9 25/51	9 14/51	9 3/51	8 43/51	8 32/51	8 21/51	8 10/51	7 50/51	7 39/51	7 28/51	7 17/51	7 6/51	6 46/51	6 35/51	11/51
3¼	12 14/53	12 1/53	11 41/53	11 28/53	11 15/53	11 2/53	10 42/53	10 29/53	10 16/53	10 3/53	9 43/53	9 30/53	9 17/53	9 4/53	8 44/53	8 31/53	8 18/53	8 5/53	7 45/53	7 32/53	13/53
3¾	13 35/55	13 20/55	13 5/55	12 45/55	12 30/55	12 15/55	12	11 40/55	11 25/55	11 10/55	10 50/55	10 35/55	10 20/55	10 5/55	9 45/55	9 30/55	9 15/55	9	8 40/55	8 25/55	15/55
4¼	14 52/57	14 35/57	14 18/57	14 1/57	13 41/57	13 24/57	13 7/57	12 47/57	12 30/57	12 13/57	11 53/57	11 36/57	11 19/57	11 2/57	10 42/57	10 25/57	10 8/57	9 48/57	9 31/57	9 14/57	17/57
4¾	16 6/59	15 46/59	15 27/59	15 8/59	14 48/59	14 29/59	14 10/59	13 50/59	13 31/59	13 12/59	12 52/59	12 33/59	12 14/59	11 54/59	11 35/59	11 16/59	10 56/59	10 37/59	10 18/59	9 58/59	19/59

C. Thurstan Holland

Plate VI.—Charts to show various Depths of a Foreign Body, for a Tube Displacement of 10 Cms.

(Reproduced by permission.)

Blake employs two metal cylinders, 8 cm. long and 2 cm. in diameter, embedded perpendicularly 6·5 cm. apart in a block of wax, with a knitting needle exactly 10 cm. long embedded in the wax halfway between the cylinders. The block is placed upon the photographic plate so that the ends of the cylinder and the needle touch the plate and stand perpendicularly to it.

Captain Shaxby employs a series of lead wires arranged as a ladder with sloping rungs, the distance between the lead wires being 1 cm. The ladder is placed upon the photographic plate so that one end of the ladder touches the surface of the plate, and the plane of the ladder stands perpendicularly to it. Two exposures are made on one plate.

The plates obtained by either Blake's or Shaxby's method supply all data for the calculation of the depth and the position of the foreign body.

These are all useful, but as they possess no marked advantage over the methods already referred to they need not be described in detail.

The object of this resumé of the generally adopted methods of localisation has been to indicate as far as possible the various ways in which a number of workers have endeavoured to attain the same end, *i.e.* the accurate localisation of a foreign body in a patient. It remains still for us to consider the best manner in which the radiologist can assist the surgeon in his everyday work of localising and removing foreign bodies from patients.

Up to the present we have considered the means of localising only, with in places a reference to the importance of the surgeon obtaining a true impression of the exact anatomical relations of the foreign body. There are situations in which a foreign body may lodge, where it is extremely difficult to obtain an accurate localisation. It is in these cases, when removal is attempted, that the accuracy of the localisation is severely tested and in which the surgeon, if he depends entirely on the localisation, may come to grief and fail to remove the foreign body.

If the stereoscopic pictures have been carefully examined by the surgeon the possibility of failure is made more remote, but there are cases in which even all the help he has had from one or more methods will not prevent a failure. What further aid can the radiologist give to the surgeon in these difficult cases ?

It has been pointed out by many workers that the single X-ray plate is misleading to the surgeon. It cannot be too strongly emphasised that accurate localisation is essential for the successful removal of a foreign body. The radiographer is as frequently at fault as the surgeon in so far as he often quite unconsciously gives inaccurate data or does not sufficiently clearly state his results.

The causes of failure in special cases are many; the commonest is the fact that the operation is performed when the region of the patient's body is not in the exact position which it occupied when the localisation was carried out.

This is a point which is not fully appreciated by surgeons. *The first essential is that the patient should at the time of operation occupy the same position as he did when the localisation was carried out.* This particularly applies to foreign bodies in the extremities. Occasionally an interval of time, amounting sometimes to days, is allowed to elapse between the localisation and the operation. Foreign bodies may change their position in the interval.

The following case illustrates what occurs at one time or another in the experience of nearly all operators.

A patient was sent for the localisation of a foreign body in the arm somewhere in the region of the shoulder. A localising plate was taken, which showed the piece of metal to be in the arm. Its position was precisely indicated. " The piece of metal lies behind the humerus and is apparently embedded in muscle." The picture presented to the surgeon was somewhat as seen in Fig. 142.

On the evidence afforded by this picture the surgeon operated but failed to find the foreign body. It was then thought that the metal was in the bone, although stereoscopic plates indicated that it lay behind the bone.

A second operation was performed with no better result, and the patient returned for a fresh localisation; other stereoscopic plates were taken, as well as several single plates from different angles.

One radiogram was taken with the patient rotated so that the shoulder was in exact apposition with the plate. (Fig. 143.) A second plate, taken with the patient flat on the back, the shoulder being about 1½ inches from the plate, showed the picture seen in Fig. 144. The arm was close to the chest wall. (It is important to record the position of limbs in relation to the body when making out a report.)

On moving the arm outwards the foreign body was seen to have changed its position on the plate; it was obviously behind the bone and close to the surface of the skin.

A final plate, taken with marks on the wounds and the position at which the foreign body was supposed to lie, gave the picture seen in Fig. 145. The foreign body was then removed with ease.

In order to avoid the recurrence of such cases it is therefore sound policy to advocate that localisation should be carried out just before the operation or even while the patient is on the operating table. For this purpose Ironside Bruce has introduced a combined X-ray and operating couch, which he has named an X-ray director couch.[1]

The Ironside Bruce Director Couch

This apparatus has been specially designed in order to facilitate the removal of foreign bodies from the tissues.

The first essential is to ensure or provide that the position of the limb or trunk, in which the foreign body is situated, shall be the same at the time of operation as at the time of observation. This can only be accomplished satisfactorily by a combination of X-ray couch and operating table, as illustrated in Fig. 146. Only one observation is necessary in the majority of cases. The use of the fluorescent screen is essential, so arrangements have been made to enable this to be done in daylight or in bright artificial light,

[1] "An X-ray director for the removal of foreign bodies in the tissues," by W. Ironside Bruce, M.D., Aberdeen. *Archives of Radiology and Electrotherapy*, June 1915.

Fig. 142.—Foreign body in upper arm.
Radiogram from first plate.

Fig. 143.—Foreign body in upper arm.
Second radiogram of the same case.

Fig. 144.—Foreign body in upper arm.
Another plate taken with the patient flat upon his back.

Fig. 145.—Foreign body in upper arm.
Result of final plate taken.

the observer wearing dark glasses for some time beforehand to render the eyes more sensitive when the fluorescent screen is used. The screen has attached to it a dark cloth under which the observer examines for the position of the foreign body.

The second essential is the provision of a guide for the operator other

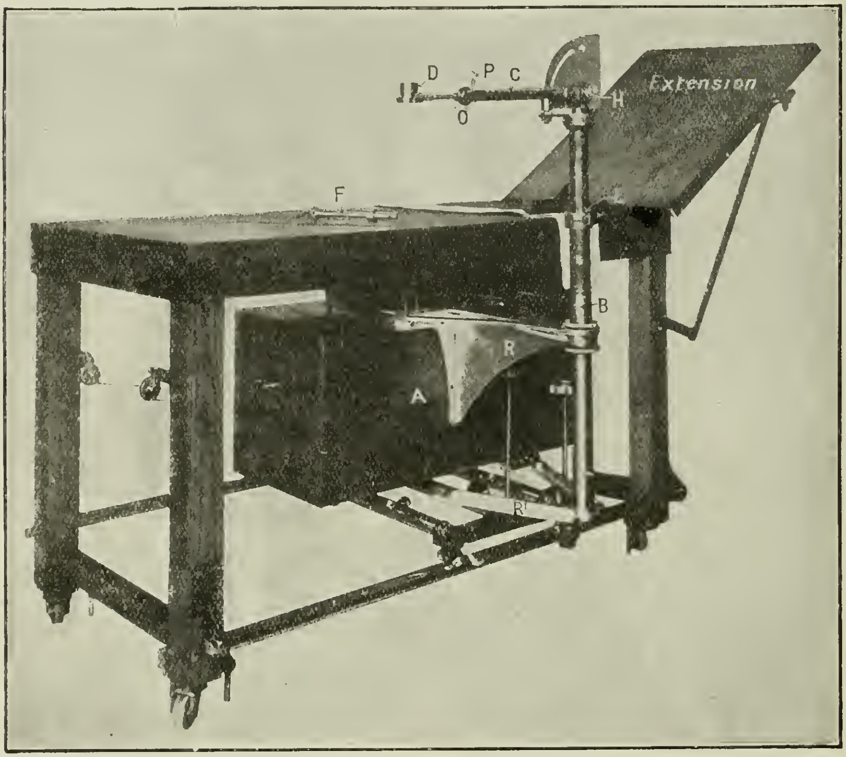


FIG. 146.—The Ironside Bruce director couch. (From *The Archives of Radiology and Electrotherapy.*)

The couch is provided with a wooden top which can be kept clean and will not absorb fluids ; a flap attached to one end allows for the accommodation of the patient in dealing with the lower limbs.

R, Rigid brackets for the support of upright. O, P, Joint and screw. H, Hinged joint.

than a mark on the skin ; a vertical guide is arranged in connection with the couch, this corresponding with the direction of radiation. To facilitate this an X-ray tube is placed in a box (A) which moves freely below the couch ; arising from the box is a strong rigid upright (B), to which is attached a cross arm (C) projecting over the couch, all these parts being firmly fixed one to the other, and moving as one piece. The upright can be raised or lowered at E.

At the extremity of the cross arm is attached a small circular fluorescent screen (D), and the cross arm can be raised or lowered so that the screen may be brought in more or less close relationship with the subject lying on the surface of the couch.

Since the box and X-ray tube are freely movable, and the upright and cross arm are firmly attached to it, the screen will maintain the same relationship to the X-ray tube in whatever position it is placed.

An X-ray tube can be so arranged that only the central radiation is used; under these conditions the shadow of a foreign body as seen on the screen indicates the exact point in space below which the body lies, and when the central radiation is adjusted to correspond with the centre of the screen and the shadow of a foreign body is brought into the centre of the screen then it must lie below the screen centre in a line between the X-ray tube and that point.

The tube-box is capable of being firmly fixed in any determined position to the couch by simply pressing a lever, and consequently during observation, when the shadow of the foreign body has been arranged in the centre of the screen, the whole, *i.e.* box, tube, upright, and cross arm, can be firmly fixed to the couch by making use of the lever. There is now presented on the screen a fixed point below which the foreign body lies.

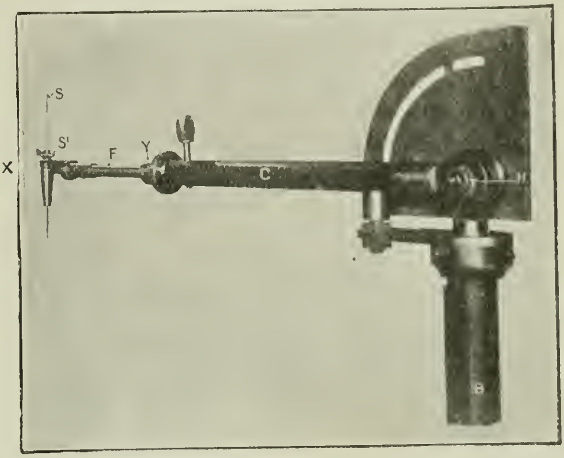


FIG. 147.—Cross arm showing metal guide and director. (From *The Archives of Radiology and Electrotherapy.*)
S, Sharp director. F, Sterilisable guide.
The cross arm C can be raised by movement of the joint H, which is constructed so that the arm is capable of returning to the same position readily and accurately. The joint from X to Y can be sterilised.

The screen is now detached from the cross arm, at the specially arranged joint seen in Fig. 147, Y, and in its place can be substituted a steelwork metal guide carrying a director (S), the point of which is arranged to correspond exactly with the centre of the screen which has been removed. The guide permits of the movement of the director only in the direction corresponding to the central radiation.

If the director is advanced through the tissues, its point will impinge against the foreign body.

The guide and director being sterilisable, they can be safely handled during the operation. A joint is provided in the cross arm to allow of the director being lifted out of the way when not required.

The X-ray observer, when he completes his examination, removes the fluorescent screen; an assistant now places in position, under strictly aseptic conditions, the guide and director, and the surgeon is in a position to proceed with the operation; by following the line of the director he should readily find the foreign body.

This is undoubtedly a most valuable mechanism and already it has proved its value in a number of cases. Great care must, however, be exercised in order that all parts of the apparatus are accurately adjusted. If this is not done the wrong line of approaching the foreign body may be followed and failure result. Small bodies, such as pieces of needle, may easily be missed, even with this instrument. The next step in our endeavour to assist the surgeon brings us to the ideal method.

The Combined Method.—This entails the use of the operating theatre, which must be rendered light-proof. For the purpose of rendering the retinæ of the operator sensitive to the appearance in the fluorescent screen white light must be abolished. Ruby light is quite strong enough for the ordinary operations if there is enough of it, and the theatre should be lighted by ruby lamps. A combined X-ray and operating table such as that described by Ironside Bruce may be employed. In the place of the director attachment a small aseptic fluorescent screen is attached to the couch. The localisation is carried out and the director used to give the line. The surgeon cuts down on the part, and if he fails to remove the foreign body in a short time the fluorescent screen is placed in position, the lights are turned down and the X-ray tube turned on, the foreign body is again demonstrated, and if desirable the forceps may be guided to it. If this combined effort on the part of the surgeon and the radiologist is used, very few foreign bodies will be missed and the surgeon will be spared many hours of anxious labour.

All that is required for this method is a suitable subject, a good X-ray tube, and an efficiently protected table and tube-box.

Barclay has introduced a forceps which has a fluorescent screen attached to it, and the forceps is connected electrically to a bell circuit which, when the foreign body is touched, causes the bell to ring.

The writer in the early days of the war had made for him a forceps which had in circuit an ordinary electric lamp ; when the circuit was completed by contact with the foreign body, the lamp lighted up.

Whichever method is employed, there is not the least doubt in the writer's mind that the most useful and accurate, also the surest method is that of close co-operation in the operating theatre between the surgeon and radiologist. It fulfils the ideal conditions of (*a*) localisation at the time of operation, therefore the most helpful ; (*b*) direction of the surgeon by the use of the X-rays before the operation, and, if a director is used, during the operation ; (*c*) the possibility of seeing at once how far out the localisation is and the certainty of correcting the mistake at the time; (*d*) any foreign body which is surgically accessible must be quickly found and removed.

The last described method is beyond question the only absolutely reliable one, combining, as it does, localisation, estimation of depth of the foreign body and operation at the same time.[1]

If these conditions are not available, then the localisation by stereoscopic plates, combined with an estimation of the depth of the foreign body, is the next best, with the important proviso that the surgeon must see the stereoscopic plates, and so far as possible he must then do his own localising, *i.e.* visualise the foreign body and its anatomical relations.

[1] A similar method to the above has been fully described by L. Ombredanne and R. Ledoux-Lebard in the *Journal de Radiologie et l'Electrologie* (vol. ii., March-April 1916).

After these two methods any of the others are equally reliable, and as the majority of foreign bodies are in limbs, the short method of Hampson or Holland, or the plate methods referred to, may be used.

In a number of cases two plates taken at opposite angles may suffice.

Localisation of Foreign Bodies in Special Localities

Localisation of Foreign Bodies in the Eye and Orbit.—(*a*) **Mackenzie Davidson Method.**—This is a method for the exact localisation of a foreign body in the eyeball. A special adjustable head-piece, fixed to a chair, is employed. It usually consists of a horizontal arm, carrying an open rectangular framework, across which two wires, one vertical and the other horizontal, are stretched, and against this the photographic plate is placed. Attached to the framework is a small rifle "sight," at the same level as the intersection of the cross wires, the use of which will be presently described, while below and to one side is a chin-rest, so that the patient does not move his head while the plates are changed and the exposures made. Parallel to the arm carrying the open framework is another arm, bearing a sliding clamp for the X-ray tube. In this way the tube always moves parallel to the horizontal cross wire. The tube is first arranged with the glistening point of origin of the X-rays on the anode exactly opposite the intersection of the cross wire, this being done by arranging the rifle "sight," the point of intersection of the wires, and the point on the anode, all in the same straight line. The distance between the point on the anode and the intersection of the wires, usually about 35 cm., is carefully measured. The patient now sits in the chair, with his head between the two horizontal arms, and with his chin placed on the chin-rest, places the side of his head (injured eye side) against the cross wires, so that they are between his head and the photographic plate, and looks straight forward, as if at a distant object, so that the visual axis of his eye is parallel to the horizontal cross wire. A piece of lead wire, exactly 1 cm. long, is fixed to the lower eyelid of the injured eye by adhesive plaster, and the distance between the upper end of the wire and the centre of the cornea in this position noted. The tube is now moved 3 cm. to one side of its original position and an exposure made. Another plate is put in position, the tube is displaced 6 cm. in the opposite direction, and another exposure made without the patient moving his head. The two plates are developed and fixed in the usual manner. The head-piece is usually made with the cross wire framework and tube-holder fitting on both arms, so that either eye can be radiographed.

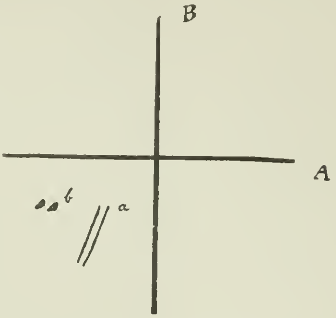
The shadows of the foreign body, if there is one, on the negatives have now to be localised, and for this purpose the cross-thread localiser is used. This is simply an apparatus for placing the negatives in exactly the same geometric conditions under which they have been made, and it has been fully described on page 163.

With these means we can now reconstruct the exact conditions under which the two skiagrams were taken. The horizontal bar is arranged so as to be at the same distance from the plate-glass as the point on the anode was from the cross wires. The two threads passing through the two notches 3 cm. to each side of the central point of the bar will, therefore, represent the paths of the X-rays when the exposures were made.

A thin piece of varnished celluloid, also having cross lines marked on it, is placed against the film side of the negative, so that the cross lines correspond in both, and the position of the foreign body is marked by pen or pencil on the varnished celluloid, as well as the shadow of the lead wire on the lower eyelid. The same is done with the other negative using the same piece of celluloid. In this way we get two shadows of the foreign body and of the lead wire in their relation to one outline of the cross wires. The celluloid with these markings is now placed on the plate-glass, with the cross lines corresponding in both. The ends of the cross threads attached to the weighted needles are placed on the markings of the foreign body in such a way that the shadow of the foreign body to the right is at the end of the thread passing through the notch on the left, and *vice versa*. These threads representing the paths of the X-rays in the two exposures, the points where they cross will represent the point in space of the foreign body.

To localise the point it is necessary to measure the perpendicular distance of the intersection of the threads from three planes at right angles to each other. The vertical distance of the point of intersection from the celluloid is measured by a pair of compasses, and this distance represents the depth of the foreign body from the skin, as the side of the head was against the cross wires. The distances between the two vertical planes represented by each of the cross lines, and the point of intersection, are measured. To do this an upright square is placed with its edge coincident with one of the cross lines, and the perpendicular distance is measured by compasses. The same is also done with respect to the plane of the other cross line. These measurements determine a point on the skin at the side of the head directly beneath which the foreign body lies, provided we know the relation of the cross wires to the patient's skin. If the foreign body is of any considerable size it is necessary to determine the exact location of each end of its shadow, but if it is very small one measurement is sufficient.

As the location of a foreign body as being at such and such a depth from the skin of the temple would not give the surgeon much practical help, one must be able to state its relation to the part of the eyeball. It was for this reason that the lead wire was placed on the lower eyelid. The location of the upper end of the lead wire is determined in relation to the three planes exactly as the foreign body was, and after this it is merely a matter of addition or subtraction to be able to tell how many centimetres the foreign body lies behind, at a higher or a lower level than, and to which side of, the upper end of the wire. We already know the distance between the upper end of the lead wire and the centre of the cornea, and as the wire is usually at the same level as a vertical line from the front of the cornea, we can give the surgeon a definite point at which the foreign body is lying in relation to the centre of the cornea, so many centimetres behind parallel to the visual axis, so many horizontally to the nasal or temporal side, and so many above or below it. For example (see diagram), suppose we have found the position of the intersection of the cross threads marking the foreign body (*b*) to be 1·9 cm. above the celluloid, 3 cm. behind the plane of the vertical cross line (B), and 1 cm. below the plane of the horizontal cross line (A), and the intersection of the thread marking the upper end of the lead wire (*a*) to be 2·9 cm. above the celluloid, 1·2 cm. behind the plane of the vertical line (B), and ·6 cm. below the plane of the horizontal line (A), then by subtraction the foreign body is 1 cm. to the temporal side, 1·8 cm. behind and ·4 cm. below the upper end of the lead wire, and as the latter is ·5 cm. below the centre of the cornea, we are able to say that the foreign body lies 1·8 cm. behind, 1 cm. to the temporal side, and ·9 cm. below the centre of the cornea, with the eye looking at a distant object.



Lastly, it should be remembered that the skiagrams taken in this way are stereoscopic, and if so viewed will give a stereoscopic effect; and as the lead wire is of the known length of 1 cm., it may be used

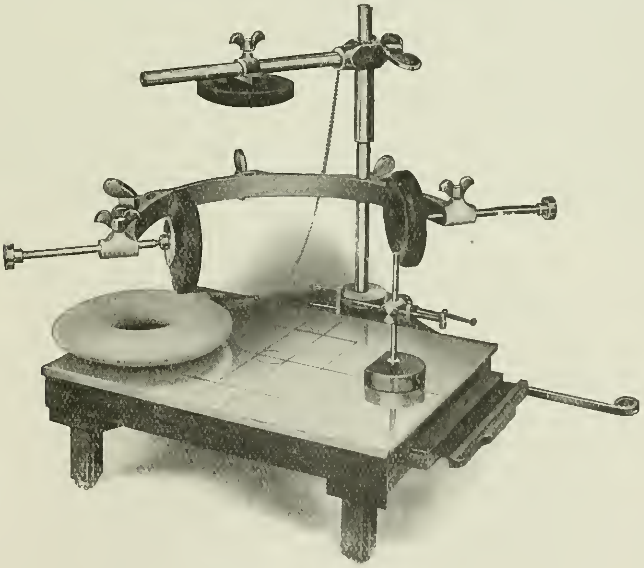


Fig. 148.—Sweet localiser.

stereoscopically as to scale to estimate approximately the size and position of the foreign body.

(*b*) **Sweet's Method of Localisation.**—Dr. Sweet's method of localising foreign bodies in the eye and orbit is carried out by means of the special apparatus designed by him for the purpose. Fig. 148 shows the device,

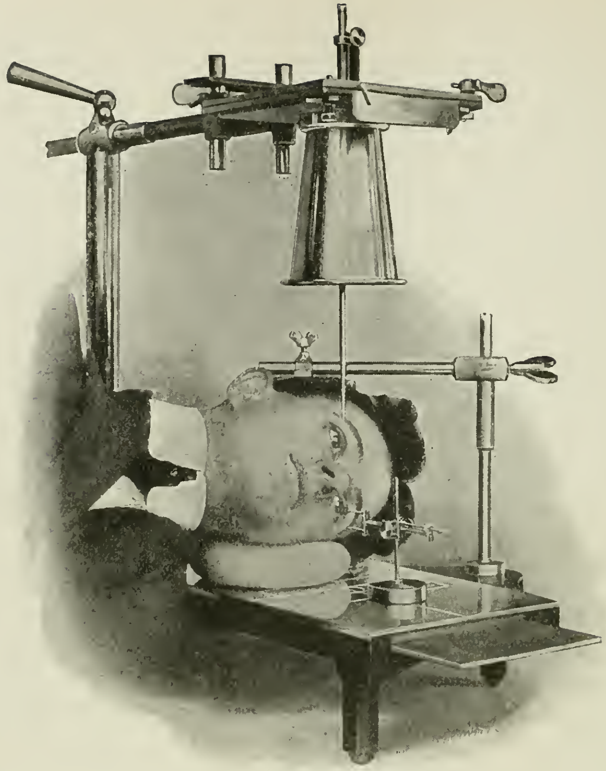


FIG. 149.—Sweet's eye localiser. Position of tube for first exposure. (A. E. Dean.)

FIG. 150.—Sweet's eye localiser. Position of tube for second exposure. (A. E. Dean.)

which comprises a head-rest for securing the head of the patient above a plate-holder, so that plates can be changed and one-half exposed without disturbing the patient. The pneumatic cushion shown is placed between the patient's head and the plate-holder.

In use, the patient's head is placed in position and the indicator shown on the right-hand side is placed in exact alignment with the centre of the cornea. The indicator is then pushed gently up to the eye itself, and when just touching it is released and carried back by a spring exactly 10 millimetres. Two exposures are made, the first with the anti-cathode of the X-ray tube in the same plane as the plate, and with one-half of the plate covered (Fig. 149). The unexposed half of the plate is then brought into position, and a second exposure made with the tube slightly tilted (Fig. 150). After development the positions of the foreign body and of the

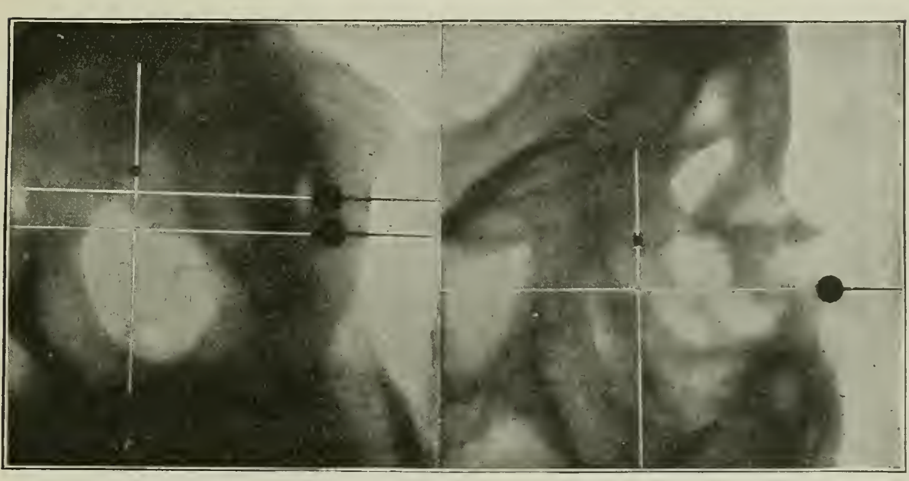


FIG. 151.—Radiograms showing the developed plate of two positions. (A. E. Dean.)

indicator are plotted upon a special chart sheet, a number of which are supplied with every instrument. It should be noted that it is not necessary to place the tube at any known distance from the plate, or to move the tube an exact distance for the second exposure. The special charts prepared on squared paper show exactly the relative position of the indicator and foreign body and the position of the foreign body in the orbit or eyeball.

The exact interpretation of the results obtained on the two plates is of some importance, and the two pictures in Fig. 151 show the orbit, with in each a shadow of the foreign body. In the negative obtained in the first position (right half) the cone and ball are superimposed and show us a single shadow. In that of the second position (left half) the cone and ball have a separate identity. It is on the relative positions of the shadows of the foreign body and of the cone and ball that the subsequent measurements which lead to the exact localisation of the foreign body are made. The measurements can with the aid of the chart be rapidly carried out;

with a little practice it should be possible to do it in a few minutes. When necessary the whole process of radiographing the orbit, developing the plate, and estimating the position of the foreign body may be carried out in half an hour.

A brief description of the steps of the Localisation by Sweet's Method.— When the two radiographs are examined it will be seen that the foreign body bears a definite relationship to the shadows of the cone and ball.

Upon the negative (Fig. 151, *a*) a line is drawn through the horizontal axis of the indicator ball and cone which are here superimposed, thereby projecting their supporting stems and establishing the usual axis of the eyeball. A second line is drawn at right angles to the first through the centre of the shadow of the foreign body. With a small pair of dividers measure the distance from the edge of the indicator ball to the intersection of the horizontal and vertical lines already drawn, then mark this distance off on the diagram chart, making a dot with a pen or sharp pencil to represent the exact distance.

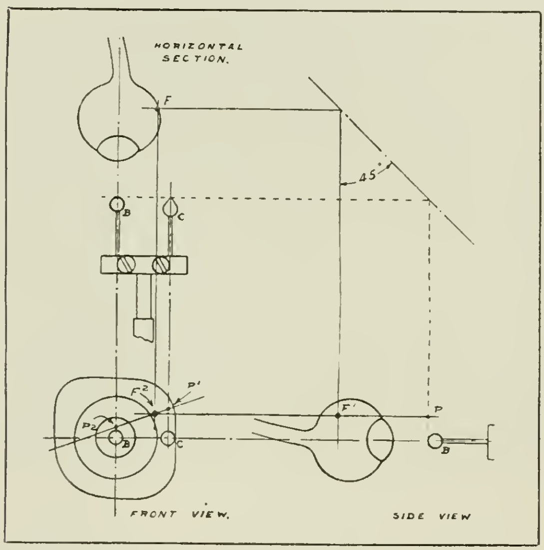


FIG. 152.—Explanatory diagram showing method of working out localisation in eyeball. (A. E. Dean.)

On the vertical line through the shadow of the foreign body measure the distance of the foreign body above the horizontal line, and indicate its position on the chart above the first dot represented by dot F^1 in Fig. 152, "side view."

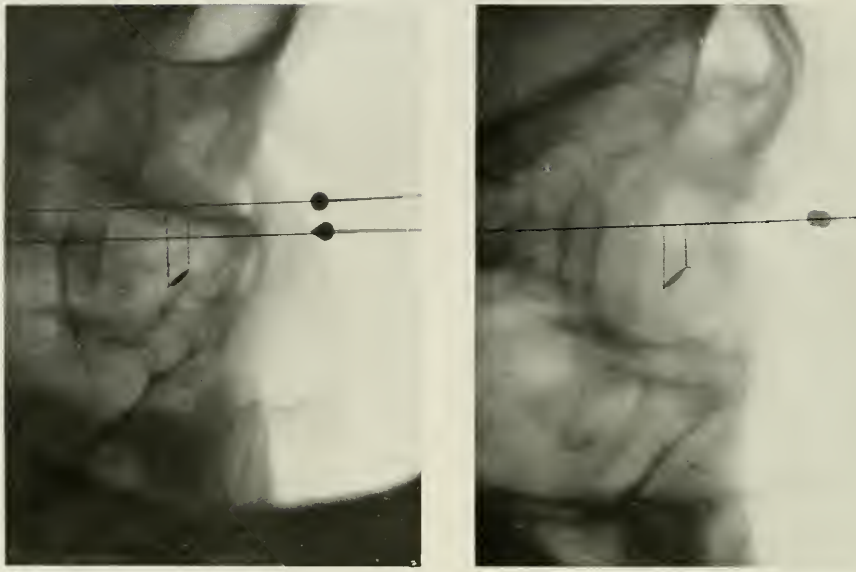
Place another dot on point P on the same horizontal line, and draw a line through these two points projecting it into the "front view" as shown.

Since the position of the localiser ball B, as shown on the chart, is the same as when the first picture was made, the location of the foreign body must be at point F^1 in the side view. It is, however, still necessary to establish its position to the nasal or temporal side of the eyeball.

Project a line vertically through F^1 to the 45° angle, and from that horizontally through the horizontal section.

Upon the other half of negative (Fig. 151, *b*), which represents the second or oblique exposure, a line is drawn through the horizontal axis of both the ball and cone, thereby projecting their supporting stems and establishing the relative position of their horizontal planes to that of the foreign body.

a



b

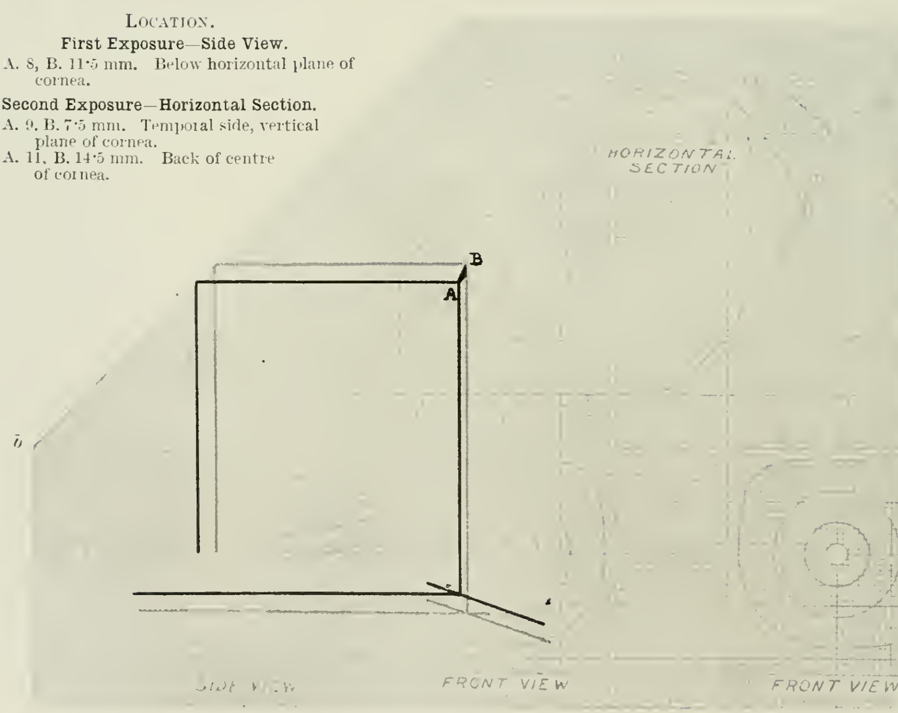


PLATE VII.—LOCALISATION OF A FOREIGN BODY IN THE EYEBALL. (SWEET'S METHOD.)

a, Reproduction of the double radiogram showing method of localisation.
b, Chart showing stages of the localisation. The foreign body was removed successfully.

A third line is drawn at right angles to the first two through the centre of the shadow of the foreign body.

Measure the distance of the shadow of the foreign body above the horizontal plane of the shadow of the ball (upper line) and mark its position by a dot on the "front view" of the chart (Fig. 152) just above the centre B as indicated by the arrow P^2, because this was the relative position of the ball when it cast the shadow.

Next measure the distance of the shadow of the foreign body above the horizontal plane of the shadow of the cone and mark the position on the chart at the point above C indicated by arrow P^1, because this was the relative position of the indicator cone when it cast its shadow; a line drawn through dots P^1 and P^2 will represent the true course of the rays in the second exposure, and its intersection with the projected line from the "side view" through points P^1 and P^2 will be the position of the foreign body when viewed from the front, while a vertical projection of a line through this point intersecting with the projected line through the "horizontal section" shows the position of the foreign body to the temporal side at point F on the "horizontal section."

The first picture (Fig. 151, *a*), lateral exposure (or the first position), charted on the diagram "side view," will be readily understood, and the method of determining the position of a foreign body to the nasal or temporal side can be easily explained if we bear in mind that the circles "B" and "C" on the front view represent the ball and cone of the localiser; and the distance that the shadow of the foreign body shows either above or below the plane of these shadows must be represented by a dot on the vertical lines, "front view," either above or below their centres, while the joining of these two dots by a straight line will indicate the direction of a ray of light passing the foreign body, the position of which will be indicated by the intersection of this line with that projected through the foreign body from the "side view."

When all these points have been worked out on the chart it is next necessary carefully to work out the exact position of the foreign body in relation to the eyeball. For convenience of rapid measurement the chart is divided into centimetre and millimetre squares. It is then only necessary to observe the relationship of the point indicating the foreign body to these squares to be able to state that the foreign body lies in a particular position in relation to the eyeball. The data may be indicated as follows:

Size of foreign body . . . .
Location . . . . . .

First exposure. Side view.

.... mm. above horizontal plane of cornea.
.... mm. below horizontal plane of cornea.

Second exposure. Horizontal section.

.... mm. temporal side, vertical plane of cornea.
.... mm. nasal side, vertical plane of cornea.
.... mm. behind back of centre of cornea.

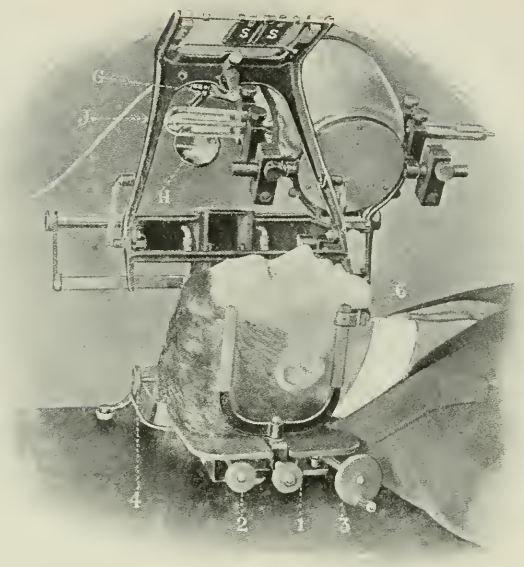


FIG. 153.—Sweet's improved eye localiser. (Snook Röntgen Manufacturing Co.)

Patient in position, awaiting adjustment of apparatus, with the upper jointed portion turned back. 1, Wheel controlling head clamps ; 2, wheel controlling lateral movement of platform on which head rests ; 3, wheel controlling vertical movement of entire optical system ; 4, wheel controlling longitudinal adjustment of platform on which head rests ; 6, strap maintaining chin in fixed position ; G, indicating ball of lead ; H, mirror ; J, frame supporting entire optical system ; S, shutters.

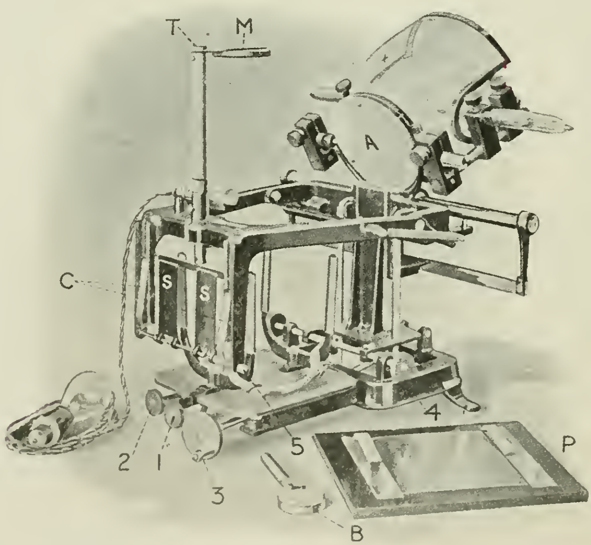


FIG. 154.—The apparatus in position for taking the first radiogram.

1, Wheel controlling head clamps ; 2, wheel controlling lateral movement of platform on which head rests ; 3, wheel controlling vertical movement of entire optical system ; 4, wheel controlling longitudinal adjustment of entire system relative to the eye ; 5, strap maintaining chin in fixed position ; S, shutters ; P, key plate ; A, aluminium screen ; T, eye-piece in telescope ; M, mirror ; C, plate holder clips ; B, reading glass for minute examination of chart.

The name of the patient, date, and other particulars are entered on the chart, and it may then be sent to the surgeon for his consideration.

The later model of this apparatus is more elaborate and mechanically more perfect, and the whole process is simplified, but the, as yet, better known one has been described because so many of the older type of apparatus are still in use.

Sweet's Improved Eye Localiser

The new apparatus (Fig. 153) consists of an adjustable head-rest, to which is attached a hinged and sliding frame. This frame carries the tube holder, the indicator, which is a small lead ball supported in a ring of transparent glass, a mirror, a telescope, and the plate holder, so that they maintain a constant relation to each other.

The telescope (Fig. 154) contains in its interior a cross wire and a small reflecting mirror, and is adjusted by a screw. On looking down the eyepiece, one adjusts the telescope until the reflecting mirror shows the cross wire to be exactly tangent to the summit of the cornea; the metal indicator will then be 10 mm. from the centre of the cornea of the eye under examination. A small incandescent lamp is attached so that the adjustment may be more readily observed. The position of the indicator is further verified by means of a small hole in the overhead mirror (Fig. 155). By an ingenious device, when the patient looks at the reflection of the indicator in the mirror above with his uninjured eye, the optical axis of his injured one is brought parallel to the plate (Fig. 155).

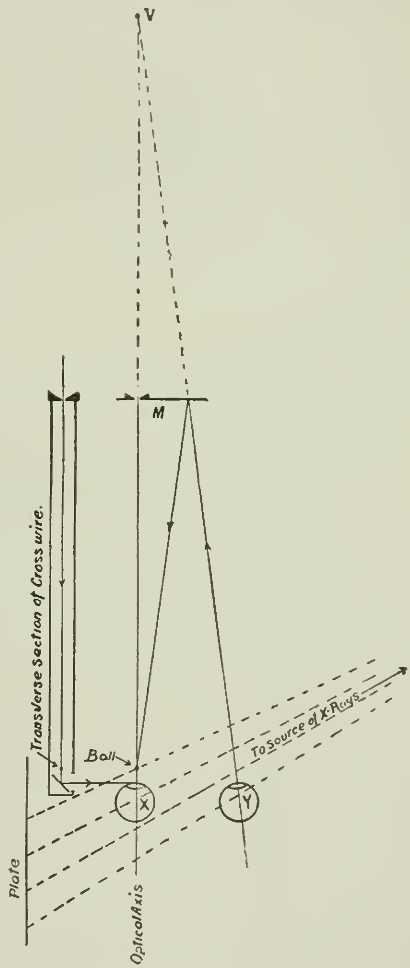


FIG. 155.—Diagram of the optical system. (Dr. A. W. Salmond.)

V, vertical image of ball as seen by uninjured eye; M, mirror; X, injured eye; Y, uninjured eye.

The X-ray tube is centred by means of markings on its lead glass shield, and the first exposure is made on part of the plate, the remainder being protected by a metal shutter (Fig. 154). A metal shutter is now placed over the exposed portion, and the tube, carrying with it the indicator and the plate, is moved a definite distance towards the patient's feet and the second exposure at once made on the previously protected portion of the plate.

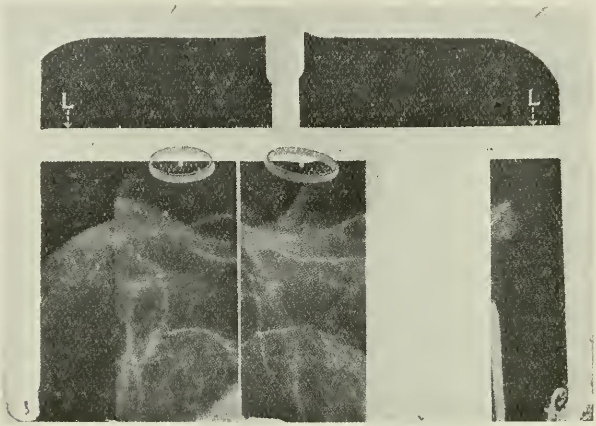


Fig. 156.—Facsimile reproduction of double radiogram of the eye, showing position of indicator ball in relation to foreign body in two planes.

It is claimed that efficient protection to the operator and patient is assured by the lead glass tube shield, the lead diaphragm, and a sheet of aluminium in its aperture.

Fig. 157.—Key plate.

After development, the plate is superimposed on a special key plate, and the co-ordinates of the two shadows of the foreign body in the two exposures read off. These readings are then transferred to a localisation chart (Fig. 158), where the position and depth of the foreign body in the eyeball or orbit is shown.

Compared with the previous localiser, the differences are entirely mechanical. They are:

The adjustable head-rest with the sliding frame carrying the tube, etc.

The more accurate and convenient method of placing the single indicator at the fixed distance from the centre of the cornea.

The device for bringing the optical axis of the injured eye parallel to the plate.

The degree of protection, the rapidity, and the ease with which the two exposures can be made on the same plate.

And, finally, in the interpretation, no lines have to be drawn on the negative, which is simply superimposed on the key plate and the co-ordinates noted and transferred to the chart, where the localisation has been mapped out mathematically.

(*c*) **Stereoscopic Method.**—This is a most useful method, and should always be employed, even when an exact localisation by other methods has been carried out. It is useful for confirmatory purposes.

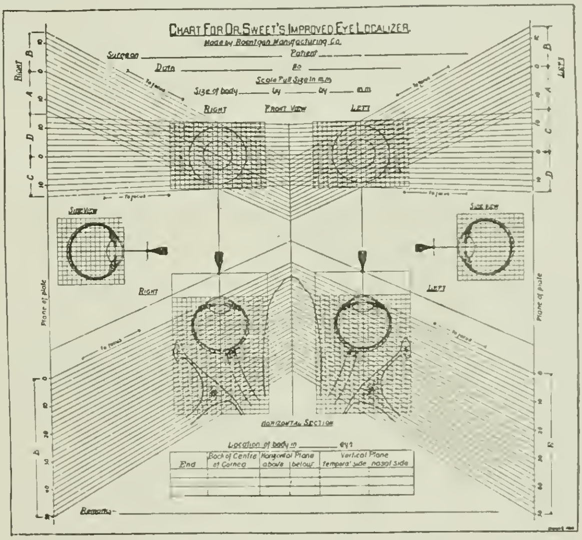


Fig. 158.—Much reduced facsimile of a localisation chart. (Figs. 153, 154, 156, 157, and 158 have all been supplied by the Snook Röntgen Manufacturing Co., who are the makers of this instrument.)

(*d*) **Simpler methods** may be employed. Two positions are necessary: (1) Lateral, (2) antero-posterior. Shadows of the foreign body are obtained in two positions on one plate by making the first exposure with the eye looking upwards, the second with the eye looking downwards. Movement indicates the position of the body in relation to the eyeball. An antero-posterior plate should also help to locate the position of the foreign body. This method is necessarily inaccurate, and can only be used to determine the presence of a foreign body. Should operation be necessary, then an exact localisation by the Mackenzie Davidson or other precise method must be carried out. In regions of the body, such as the thorax and abdomen, the same measures may be employed. Stereoscopic radiograms of the thorax in the antero-posterior and

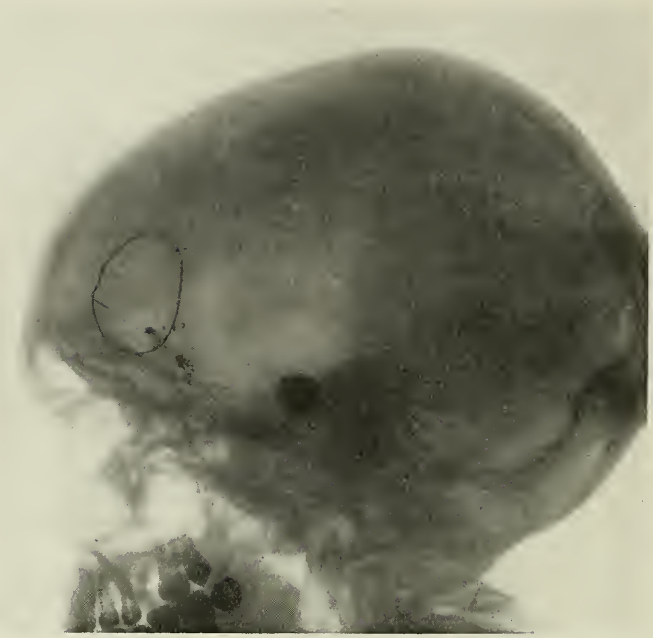


Fig. 159.—Shrapnel bullet in skull. Piece of wire indicates point of entrance and fragments of shell. The bullet was successfully removed after stereoscopic localisation.

Fig. 160.—Radiogram of a skull after operation for the removal of a foreign body.

lateral positions should suffice to indicate the position of the foreign body. The cross-thread method of localisation should be employed as a confirmatory measure.

Fig. 161.—Foreign body in region of superior maxilla.

Fig. 162.—Fragment of shell in region of hip-joint.

Localisation of Foreign Bodies in the Skull.—The methods available are (*a*) stereoscopic; (*b*) stereoscopic combined with Mackenzie Davidson method.

A simple method may be employed when it is not possible to have access to the two methods referred to. It is one which any one possessing an X-ray installation can carry out, and which has proved useful in many instances. Three plates are required: (1) Right lateral, (2) left lateral, (3) antero-posterior. For the localising of foreign bodies in the head the skull is divided into sections by means of flexible wire. A piece of wire is fixed in the longitudinal diameter, extending from the nasion in front to the external occipital protuberance behind. A second wire is carried from the nasion through the centre of the external auditory meatus backwards to end below the occipital protuberance. A third wire is carried vertically over the skull from one external auditory meatus to the other. Three plates are taken and compared. When the foreign body is sharper on one plate

Fig. 162*a*.—Foreign bodies in the region of shoulder-joint.

than on the others it indicates that it is nearer to the side on which it is sharpest. The antero-posterior plate confirms this observation. The lateral

Fig. 163.—Fracture of tibia, portions of shell in limb.

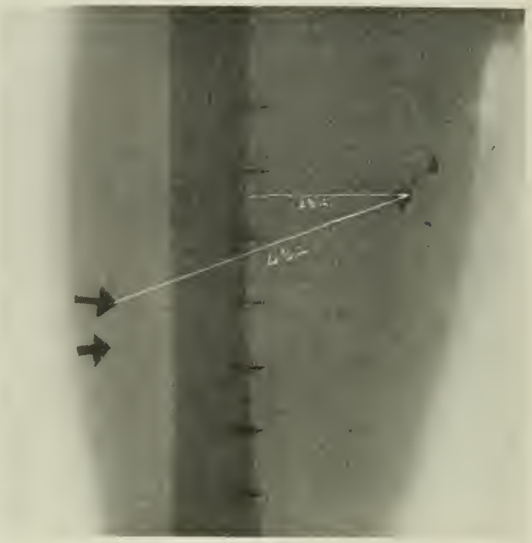


Fig. 164.—Fragments of bullet in limb; arrows indicate position of wounds. Graduated scale over bone. Horizontal line indicates distance from edge of bone, oblique line distance from upper arrow.

Fig. 165.—Fracture of shaft of the ulna. Gunshot wound. The wires indicate points of entrance and exit.

Fig. 166.—Antero-posterior view of same fracture as in Fig. 165.

pictures also serve to show the relationship of the foreign body to a well-known landmark at the base of the skull.

Localisation of Foreign Bodies in Region of Hip and Shoulder.—

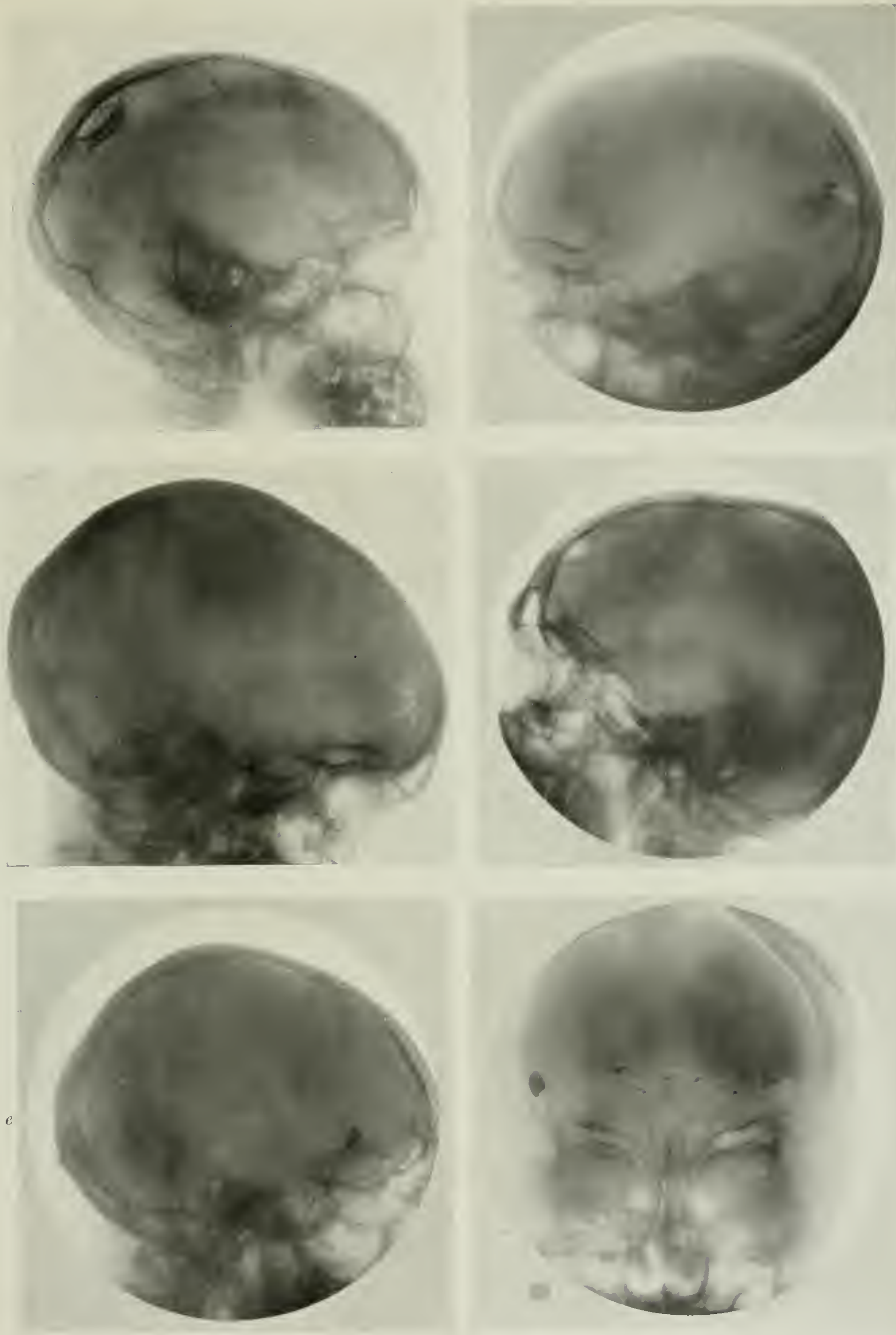


PLATE VIII.—Skull Injuries.

a, Depressed fracture of vault of skull.

b, Depressed fracture of skull showing fragments of bone driven into the brain.

c, Fissured fracture of left side of skull passing down to the base of skull.

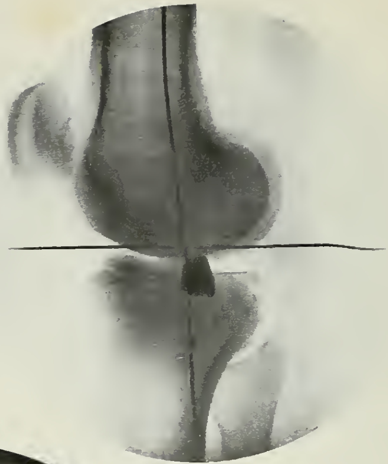
d, Gunshot injury in frontal region of skull. The skull has been trephined for the removal of foreign body ; note thickened edge of trephined wound.

e, Large piece of metal in skull above orbital plate ; many small pieces on a higher level.

f, Fracture of frontal bone—gunshot injury ; entrance wound on left side, and track of bullet shown by fragments of metal. A large piece of metal on right side of skull.

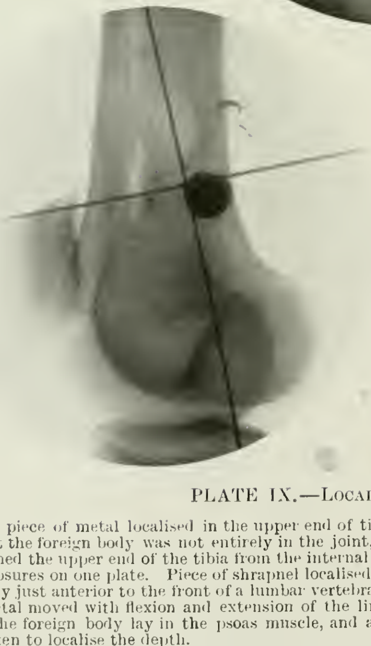
a

b



c

d



e

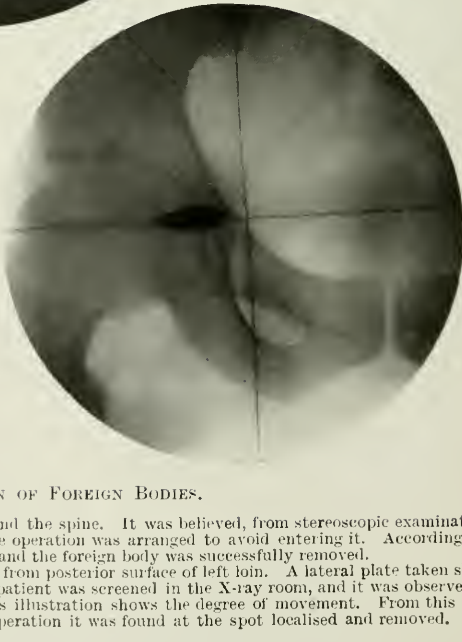


PLATE IX.—LOCALISATION OF FOREIGN BODIES.

a and *b*, A piece of metal localised in the upper end of tibia behind the spine. It was believed, from stereoscopic examination of the plates, that the foreign body was not entirely in the joint, and the operation was arranged to avoid entering it. Accordingly the surgeon trephined the upper end of the tibia from the internal aspect, and the foreign body was successfully removed.

c, Two exposures on one plate. Piece of shrapnel localised 8½ cms. from posterior surface of left loin. A lateral plate taken showed the foreign body just anterior to the front of a lumbar vertebra. The patient was screened in the X-ray room, and it was observed that the piece of metal moved with flexion and extension of the limb; this illustration shows the degree of movement. From this it was inferred that the foreign body lay in the psoas muscle, and at the operation it was found at the spot localised and removed. Other plates were taken to localise the depth.

d, Foreign bodies localised at lower end of femur. One near inner side close to entrance wound and the other (larger) on the outer side. The plate also shows hole through the shaft of femur. The localisation was confirmed at operation. This figure illustrates a defect in technique; the cross-wires have not been arranged in proper position, for the movement of the tube must always be in the same plane as one or other of the cross-wires.

e, Bullet in region of hip-joint. It was localised as to depth from the posterior aspect and said to lie *behind* the posterior lip of acetabulum; depth at broad end, 7 cms., at point, 6 cms. At operation the bullet was found lying close against the posterior lip of acetabulum, embedded in fibrous tissue, and was removed.

In these regions it is impossible to get more than one position readily, though in exceptional cases it may be possible to get an approximately lateral view, so stereoscopic radiographs should be taken. These combined with the Mackenzie Davidson method give the most accurate results.

Localisation of Foreign Bodies in the Limbs.—In a number of instances it may be possible to locate the foreign body by screening alone. In other instances one of the methods described by Mackenzie Davidson, Hampson, Shenton, and others may be used. The position of the foreign body is ascertained and a mark placed on the skin surface immediately over it. The tube is then moved and the second position of the foreign body noted. It is then a matter of calculation to estimate the depth of the foreign body. Hampson does so by means of the graduated scale, Shenton by the use of the probe with a bulging point on it, and by placing the limb at right angles to the position it occupied when the mark was placed over the foreign body.

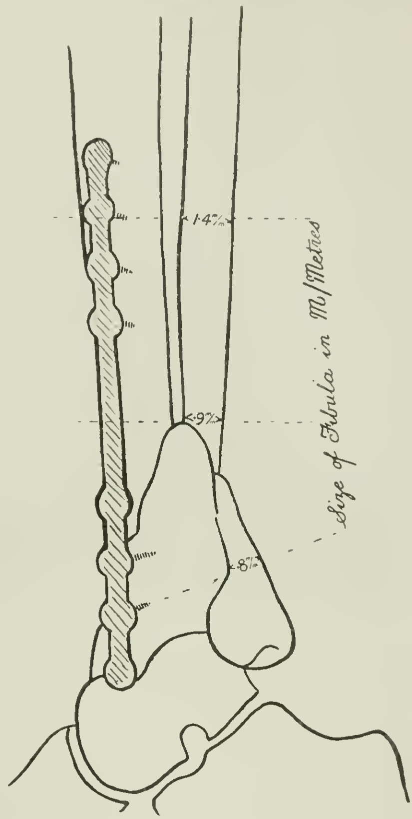


Fig. 167.—Diagram of the picture shown in radiogram (Fig. 168), lateral position, to illustrate the method of measurement of fibula, ascertained from stereoscopic plates.

Localisation of Foreign Bodies in Deep Parts of the Body.—In several of these regions the localisation of a foreign body is a matter of extreme difficulty, notably in the thorax, abdomen, pelvis, axilla and region of the hip. The exact position may be worked out both stereoscopically and by the Mackenzie Davidson method, and yet the necessity of avoiding anatomical structures may render the subsequent removal difficult. In some cases it may be helpful to take a lateral view of the thorax or spine. This may enable us to say at once where the foreign body lies in relation to a bony landmark, but for exact localisation it is necessary to use the cross-thread method.

The triangulation method of localisation can be used in other ways than for the determination of the position of a foreign body. The method may be employed for ascertaining the position and size of lesions of the intrathoracic or abdominal organs. it can also be used to measure the size of bony structures within the skull. The radiographer is occasionally asked to measure the size and thickness of a particular bone which the surgeon may require to deal with.

Figs. 167 and 168 illustrate its application to a case of ununited fracture of the fibula. The measurements were obtained by taking stereoscopic

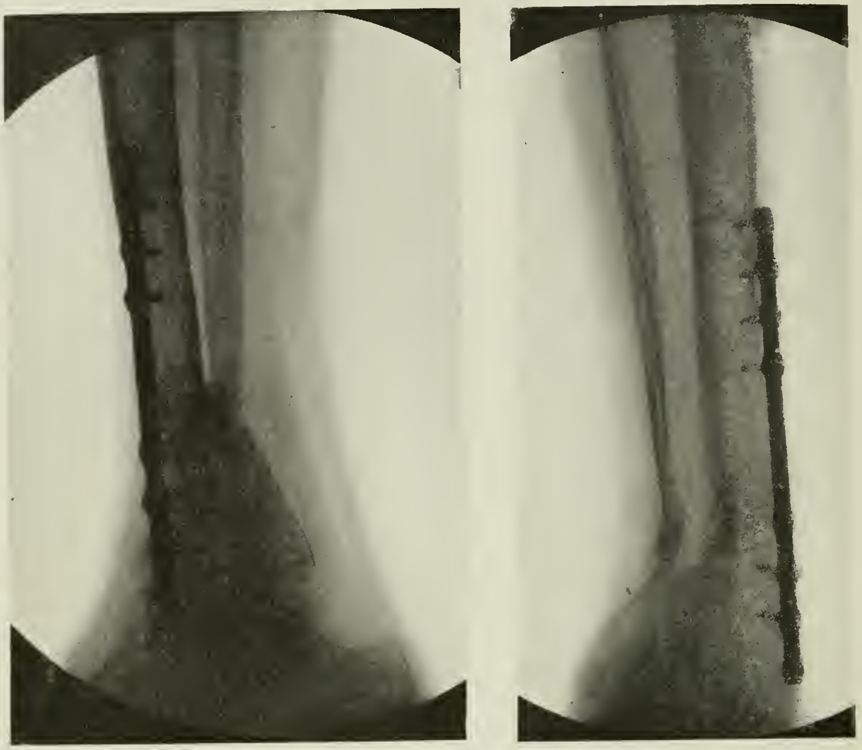


FIG. 168.—Radiograms of the lateral and antero-posterior view of a fracture of the tibia and fibula. The tibia has been plated, but the fibula shows non-union.

plates in two diameters. These were then measured off in the usual way and the actual thickness of the bone recorded for the use of the surgeon.

Radiography as an aid to the Surgeon and Physician in War Time

The exigencies of the present war have led to a great extension in the use of X-rays. Both in diagnosis and in therapy has this been noticeable. It is, therefore, well to briefly indicate the varieties of cases in which Radiography is likely to prove helpful.

The principal field for the use of X-rays is in the recognition and the localisation of foreign bodies. This alone justifies fully the extensive advantage which has been taken of radiography by the surgeon.

The second in importance is the diagnosis and treatment of fractures. Valuable help can be rendered in estimating the position of the fragments both before and after treatment, and the subsequent stages of healing of the damaged bone can be demonstrated. This latter is a most useful service, because it is possible to study the process of healing and the definition and absorption of callus. Most valuable information will accrue in this relationship as time progresses. Our information as to the various types of fractures will be added to, and new and hitherto undescribed forms, due to the action of high explosive shells, etc., will be recognised.

An interesting development in the diagnosis of injuries and diseases of bone has been due to the extensive use of X-rays as an aid to the recognition of sequestra and their behaviour subsequent to the initial injury. In some cases of fracture the bone is shattered into many pieces of varying size. The history of these fragments follows definite courses according to whether or not they are cut off from their blood supply ; all conditions are met with, from that of small sequestra to large pieces of bone which show stages of progressive necrosis. Partially dead bone may be seen in process of separation, and the distinction that can be shown between bone which is "alive," and likely to join up with other fragments to form a useful support and aid in the union of the fractures, and that which is "dead" or likely soon to die, must be extremely useful to the surgeon. The power to recognise a piece of bone which is not likely to be useful in the process of repair will lead to early removal of the fragments, and thus effect a great saving of time in the progress of the case. The reason of the absorption of lime salts, in some of the cases, with a consequent rarefaction of the fragment and the death of the sequestrum is also a difficult matter to explain. Another fragment may show a distinct increase in density from the deposit of bone salts in its structure subsequent to the injury. These all have a definite significance in the physiological processes of healing, in contradistinction to the pathological process of disease, which may also be present as a result of sepsis or other morbid condition. When time has been allowed to elapse and the accumulated observations of many workers become known, valuable information will be at hand regarding many physiological and pathological processes which are at present very difficult to understand. Suffice it to state that the present opportunities are great for the radiologist to acquire knowledge which could be obtained in no other way and at no other time.

Another interesting field for investigation will be found in the behaviour of bone in the vicinity of an injury, and particularly of those bones in the region of joints which have as a result of the injury become immobilised. The extreme rarefaction which is seen in bones around a joint in the vicinity of which an injury has occurred has been long recognised as due to the absorption of lime salts from the matrix of the bones, but it is by no means clear whether this is due to interference with the blood supply or direct injury to nerves or is merely the consequence of loss of function.

These conditions have been recognised for many years. When we have had an opportunity of watching and recording the many changes which are now being seen and carefully analysed, the time may have arrived when an answer may be given. The matter should not be allowed to pass into obscurity, because it is probable that when we understand more about these processes, it may be possible, by investigation along similar lines, to clear up many puzzling problems connected with disease of bone. Absorption of lime salts occurs in other conditions than traumatic lesions; many diseases show similar phenomena, particularly those conditions of bone associated with joint diseases. Thus we find changes in tuberculosis of bones and joints; chronic inflammatory changes, specific and simple; in rheumatoid affections and in malignant disease of bone. In all of these we have progressing side by side, rarefaction and condensation of bone, and necrosis resulting in sequestra formation.

In malignant disease of bone, which is generally secondary, the bone may retain its original shape while its structure may be greatly changed. Radiographic examination will reveal profound changes in the matrix, indicated by rarefied areas which have almost the appearance of abscess cavities. These changes are found particularly in the long bones and in the spine. It is occasionally found that considerable portions of the spine and other bones are riddled with these small cavities, although the patient is able to get about without difficulty, and the only clinical evidence is deep-seated pain. These changes are in part due to absorption of bone salts, but no explanation of their occurrence or why they remain localised is forthcoming. Space forbids a lengthy discussion of these many interesting problems, but we trust that enough has been said to indicate lines of research to others and to stimulate workers with the desire to grapple with these and many other problems of a like nature.

Another interesting result of injuries to bone and in the region of joints is the occurrence of traumatic myositis ossificans. Many examples are met with in practice at the present time, and work is at present being done by Mr. Rowntree and Dr. Martin Berry and many others, particularly in regard to the behaviour of sequestra; when the results are published they may throw considerable light on the many problems involved.

The occurrence of gas within the tissues in cases of injury accompanied by septic infection is another highly interesting subject; this matter is dealt with at greater length later on.

Diagnostic aid is being rendered by the radiologist in other directions. The occurrence of gunshot injuries in the thorax has given a great opportunity to investigate such conditions in pneumothorax, haemothorax, pyopneumothorax, empyema, and chronic pleurisy. The radiography of the heart and its behaviour when foreign bodies have found their way into its vicinity, and even into its interior, is also very helpful to the physician and surgeon. Several most interesting cases have been recorded.

The diseases of the lungs and pleura often require to be investigated by the radiologist with a view to settling the question of the fitness of recruits to serve in the army. The demonstration of positive evidence of disease in these men will be a sufficient answer in many cases. Another interesting point is when a man shows evidence of disease; we then have to ascertain its extent and the effect it will have upon his usefulness to the country at the present time. A man giving evidence of unfitness for active service

a

b

PLATE X.—GAS GANGRENE AND GAS IN THE TISSUES.

a, Gas gangrene showing the course of the gas along the muscle sheaths. *b*, Gas bubble in the vicinity of shell casing.

PLATE XI.—Gas Gangrene.

a, Extensive and diffuse infiltration of the calf without any bone damage. Foreign body present.

b, Radiographed on the third day. An extensive gas infiltration seen behind the knee. The patient did well after three incisions.

c, Radiograph four days after the wound was infected. Several discrete bubbles, together with a fair amount of diffuse infiltration. There is extensive bone damage, and the foreign body is seen in situ.

(From radiograms by Dr. Martin Berry.)

may be invaluable to his country in an administrative or expert capacity. These are all points which the radiologist can help to elucidate.

A great deal of work is being done in the investigation of the condition of the alimentary system by means of the opaque meal. It should be possible to ascertain definitely the appearance of the opaque meal in the healthy stomach and intestines, in a way which has never been possible before. An effort should be made to standardise the normal meal by making observations on a number of healthy subjects.

Gas in the Tissues

Gas Gangrene.—The complication of gas gangrene is not a new one. It was recognised by Ambroise Paré in the sixteenth century. It is not a simple infection due to one organism. It is often sudden in its onset and disastrous in its consequences. The prevalence of this complication at the present time is due to the infection of the clothing, an inevitable sequence to trench warfare; when a wound of the tissues occurs, fragments of infected clothing are carried in with the shrapnel or other foreign body and lead to changes in the tissues which vary in rapidity of onset and progress according to the prevailing organism. Two fundamental ideas have to be recognised: (1) it is a polymicrobic invasion, consisting of aërobes as well as anaërobes, showing itself in a clinically polymorphous infection; (2) that the development of the disease is favoured and the virulence of each infecting organism is exaggerated by the association of several.

The organisms chiefly responsible for the occurrence of gas gangrene are (1) *Vibrion septique*, and (2) *Bacillus perfringens*. The other organisms found play generally a secondary part. Dr. Guermorprez, Professor of Therapeutics at Lille, has published details of the work of many investigators, and has ably summarised their results.[1]

The symptoms and appearance of gas gangrene vary according to the predominant organism present at the time of injury. Some cases show gas without gangrene, others show gangrene without gas. Emphysema may travel very rapidly in the tissues. The period of incubation also varies; the graver forms commence 24 to 28 hours after the wound, while the slow form begins on the fourth day.

The symptoms vary according to the type. The temperature is generally about 100° F. Discoloration of the skin occurs, and the presence of the gas may be detected by the pressure of the finger upon the surface. Radiography has proved itself to be most useful in aiding the surgeon to recognise at the earliest possible moment the occurrence of gas gangrene.

Dr. Woodburn Morison has published a short account of the condition.[2] He recognises two groups:

1. Cases of true gas gangrene.
2. Cases of localised gas formation.

[1] *Gangrène gazeuse pendant la Guerre de 1914–1916*, par F. R. Guermorprez, Professeur de Médicin, Major. Tomes i.-iv., 2me édition Refondue. Paris, J. Russet, 1916.

[2] "Gas in the Tissues," J. Woodburn Morison, M.B., C.M. *Archives*, December 1915.

Group 1. **True Gas Gangrene.**—"In these cases the gas formation was exceedingly rapid, spreading along the muscle sheaths, and finally leading to complete disintegration of the muscles. The quantity of gas evolved was considerable, the part affected being swollen and so tense that the gas could be heard escaping when an incision was made. The smell of the gas was indescribable, and in advanced cases a diagnosis could be made without an X-ray examination. As amputations had to be done in many of these cases, the X-ray plates were often of value as evidence of the necessity of the operation, especially in cases where the original injuries were not of themselves serious."

Group 2. **Localised Gas Formation.**—"Here I found that the gas formed in the vicinity of the metal and collected in bubbles of varying size —forming slowly and not exhibiting the same tendency to spread along the muscle sheaths. It was possible by X-ray examination to demonstrate its presence in minute quantity long before it could be diagnosed otherwise.

"The early detection of the presence or absence of gas in the tissues is important. If present, surgical interference is at once indicated, and if absent, one point at least has been established in favour of leaving well alone. I found that even a negative X-ray diagnosis could be made with some degree of certainty and was regarded as valuable to the surgeon."

Dr. Agnes Saville describes three conditions,[1] and both workers obtained their experience in France.

"(1) Simple *swelling*, with a pale, misty outline which sometimes fades a little in indefinite areas in much the same way that a white fog looks thin in some parts of a landscape. The degree of the swelling gives some evidence of the amount of infection present. This form is found when *Bacillus perfringens* is the chief organism, and is probably due to the œdema which is usually associated with *perfringens*. A woman with œdema of one side of her arm showed just the same pale, misty hue in the situation where clinical evidence of œdema existed.

"(2) *Swelling*, and in addition there is a *cloud-like* outline, an appearance as if the flesh were replaced by dark woolly clouds. This aspect is due to infiltration of the tissues by the gas. In some cases there are some rounded or oval-shaped dark outlines, where the gas is sharply demarcated. The diffuse cloudiness is the more common variety by far. For a long time, when a group of gas bubbles about the size of a threepenny piece occurred in close proximity, I believed the picture was due to a plate flaw. The *diffuse cloudiness* was in the great majority of cases associated with *perfringens* and *sporogenes* together. In gas *bubbles* frequently *perfringens* is the only anaërobe.

"(3) *Striation.*—This third appearance was exceedingly rare. There were two types—coarse and fine. The fine striation occurred in only two of our cases, but Dr. Pech has a large collection of plates illustrating this rare condition. The dark lines of gas infiltration map out the individual

[1] "X-ray Appearances of Gas Gangrene," Agnes Saville, M.A., M.D. (Glasgow), M.R.C.P. (Ireland). *Archives of Radiology*, December 1916.

muscle fibres in such a definite manner that the plate resembles a drawing of the muscles of a limb.

"The coarse striation was also rare. It was associated with considerable swelling, whereas the fine striation cases were not so swollen at the time of the skiagram as their serious clinical condition would have led one to expect. The coarse striation occurred in limited areas, the lines of division were straight and were always seen in a longitudinal direction. The intensity of the infective process seemed to cause dissociation of groups of muscle fibres in an area which was usually about 2 inches long.

"In one of the cases of fine striation, the *Vibrion septique* and *Bacillus perfringens* were found in the depth of the muscles and in the blood. In the other *Bacillus histolyticus* and *Bacillus fallax* were the uncommon germs present. Both cases were fatal. In the cases with coarse striation *Bacillus œdematiens* and *Bacillus Hibler IX.* were the most frequently occurring organisms. *Perfringens* was present in every case.

"*Fallacies to be avoided:* (1) Actual loss of tissue, which is frequent with the extensive wounds of present-day warfare, causes a dark, irregularly outlined aspect which may mislead the radiologist who has not seen the wound, but cannot possibly mislead the surgeon. (2) I have seen an extensive ecchymosis give the swollen, misty, and fading away appearance exactly resembling the common œdematous *perfringens* infection. I have not seen enough cases of ecchymosis to be in a position to state whether it can be distinguished from the *perfringens* invasion, but there could not be any clinical difficulty in the differential diagnosis. (3) I believe abscesses may simulate gas bubbles. As *perfringens* is so all-prevalent in military surgery to-day it is difficult to say whether in these abscesses some gas was not present. In any case the indications for the surgeon are similar in both cases."

Dr. Martin Berry, working at the Herbert Hospital, Woolwich, describes the two main types thus.[1]

"Radiographically speaking, there are two main types of gas formation:

"1. Where there are a comparatively small number of discrete bubbles, though individual ones may be of large size.

"2. Where there is an extensive and diffuse gas infiltration. In either condition the gas may be found under considerable pressure. Further experience may lead to extension of this classification.

"There are certain fallacies to be guarded against in making a diagnosis of the presence of gas:

"1. The actual wound may involve such a loss of tissue as to cause increased radio-transparency of the part. This is very common, but is easily distinguished and is hardly likely to lead to error.

"2. Bubbles of air may be trapped within the tissues. This is not so common and the shadow outline is apt to be less defined. There is only one case in the series where this diagnosis was suggested.

"3. If the wound has been syringed with peroxide of hydrogen, oxygen

[1] "The Recognition of Gas within the Tissues," H. Martin Berry, M.D. *Archives of Radiology*, December 1916.

bubbles may be present under considerable tension. Enquiries should be made, therefore, as to whether the wound is known to have been so treated and due caution exercised. This is particularly the case when the bubbles are few and discrete, and, in the present state of our knowledge, there is no certain means of differentiation, though, if the gas be situated at some distance from the track of the wound, it is more likely to be the result of the infection than of the treatment. In diffuse infiltration this is practically certain to be the case and diagnosis can be made with confidence."

The general consensus of opinion is that no one organism is specific—at one time it is *B. perfringens*, at another *Vibrion septique*, perhaps, also, *Vincent's fusiform bacillus* or *B. Coli*, and many others. Generally it is a microbic association that is responsible for the trouble. Some writers maintain that characteristic radiographic appearances are found when a particular organism is predominant.

The radiographic evidence is helpful to the surgeon in determining (1) the presence of gas in the tissues, (2) its position and extent. When this is determined it clearly indicates the need of early operation.

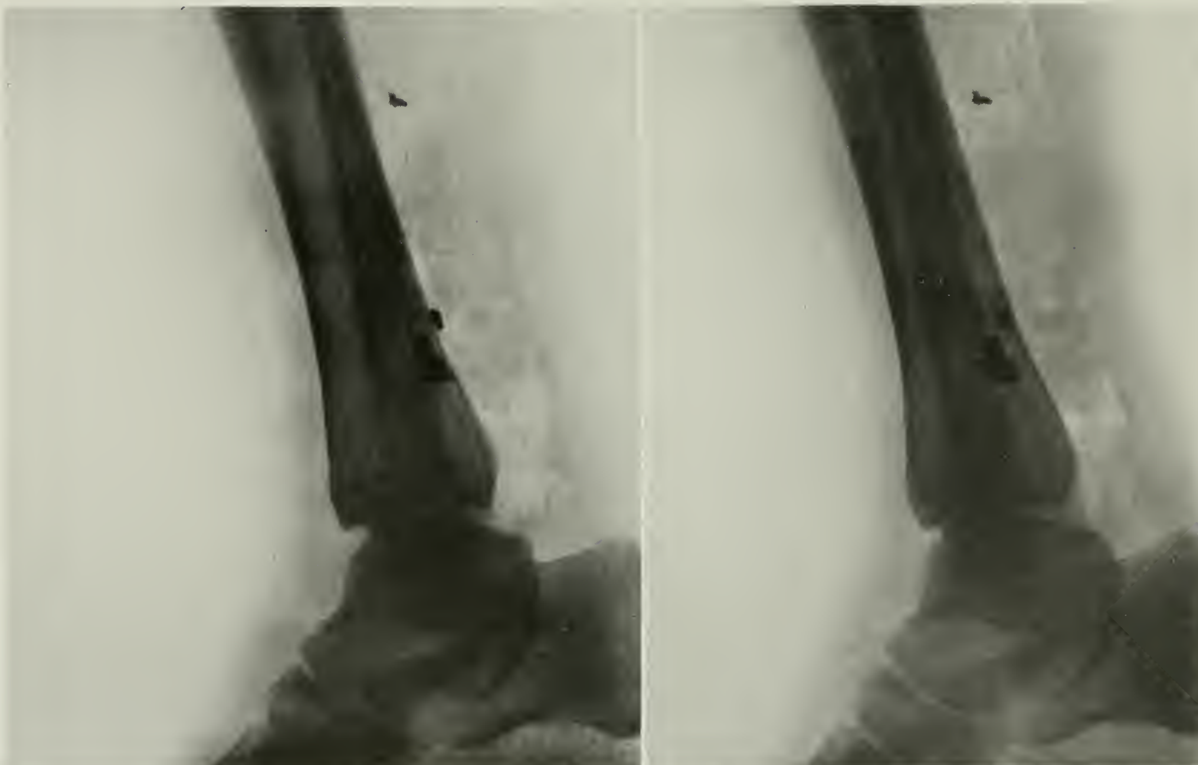


PLATE XII.—Gas Gangrene.

Foreign bodies in leg, with gas gangrene. Tetanus supervened and the patient died. The above are from stereoscopic radiograms, and can be viewed through a hand stereoscope ; but the screen used in the half-tone process partially destroys the stereoscopic effect.

RADIOGRAPHY OF THE NORMAL BONES AND JOINTS

A thorough acquaintance with the normal appearance of these parts is necessary on the part of the radiographer before he proceeds to an interpretation of the many variations which he may be called upon to describe. Not only must he know the chief bones and joints from any one aspect, but he should by a careful study of the parts know them from any point of view. It may not be always possible to get the patient into the position of ease which is generally the one in which the parts can be radiographed most readily. A patient suffering from an injury to a joint may not always be able to take up a position on the X-ray table which will enable the operator to radiograph the part to the best advantage ; the apparatus may have to be adapted to the patient instead of the patient to the apparatus, hence it is necessary that the operator should be familiar with the parts from several points of view. In ordinary cases of fracture of the bones in the vicinity of a joint it is always a good rule to radiograph the parts in at least two positions.

The Skull and Accessory Sinuses

There are several positions of the skull which lend themselves to the production of good radiographs. Of these the lateral is the most useful, as it gives a general impression of the whole skull and soft parts, the articulations at the base, and a lateral view of the cervical vertebræ. There are various modifications of this position, to be considered in detail later, which are extremely useful when special areas require to be investigated. To get good radiographs of the skull, it is essential that the head should lie flat on one side, and be held absolutely still during the exposure. A useful instrument for fixing the skull is that supplied with the Sweet localiser, since it may be used in all positions of the skull. It has two or more clamps attached to a base, upon which the plate may be placed. These clamps keep the head in the same position while several radiographs are obtained.

Among the numerous pieces of apparatus which can be used for the radiography of the skull, there may be noted a simple chair, devised by Dr. Martin Berry, which promises to answer all the requirements of the radiographer. This apparatus has a movable back, with a circular hole in it. The movement is in the vertical direction, to adapt the central hole to the varying height of the patient when seated in the chair. Side clamps fix the head after the necessary angle has been determined. This angle is obtained by a rod moving along the quadrant of a circle. The head is placed to correspond with the angle on the apparatus, the plate being placed always at the same angle in relation to the tube. An efficiently protected tube-box is placed on the back of the chair. It can be accurately centred, and has both vertical and transverse movements to facilitate rapid adjustment behind the part to be radiographed.

The Radiographic Base Line.—The base line of the skull can readily be determined by a method elaborated by Dr. R. W. A. Salmond and the author. This method is based on a series of measurements made on the dry skull, and afterwards applied to and verified on subjects in the post-mortem room; they have also been confirmed on the living subject.

In practice it has been found accurate for application to the various types of skull met with, though in exceptional yet still normal types its accuracy will be lessened.

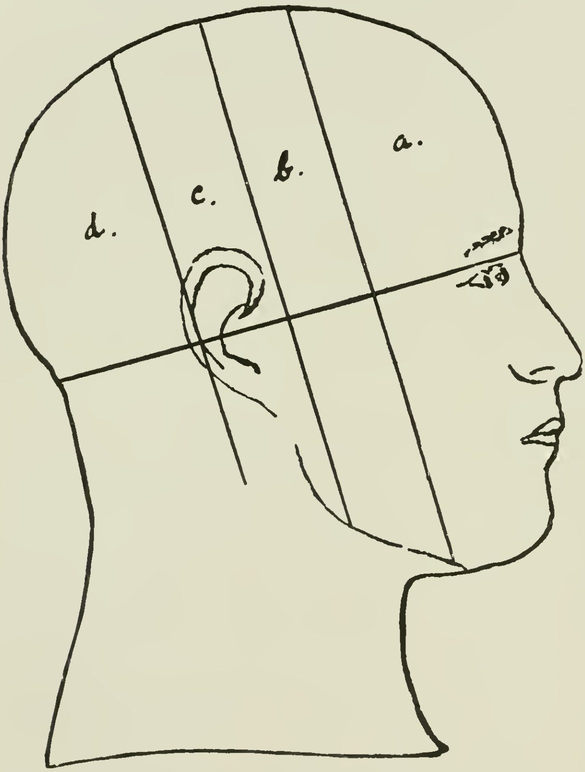


Fig. 169.—Diagram to illustrate the radiographic base line. From *Archives of Radiology*.

A base line, which may be called the radiographic base line of the skull, is made use of. It is determined by drawing a line from the nasion, *i.e.* the mid-point of the suture between the frontal and nasal bones, through the centre of the external auditory meatus, and continuing it to the mid-line at the back of the head (Fig. 169). The length of this is measured, and on it three points are marked, at the one-third, the one-half, and the two-thirds distance from either end; usually it is most convenient to measure from the front.

Through these points perpendiculars to the base line are drawn, dividing the head into four areas, by three lines which run downwards and forwards and are intersected by the base line. The lines may be marked on the head with a skin pencil, or by thin wire if they are to be reproduced on the plate. This base line was chosen because the nasion is a fairly constant point and easily determined; the external auditory meatus is also constant, and the whole line corresponds exceedingly well with the base of the skull.

The external occipital protuberance was avoided because it is variable and not always easy to feel, and moreover, a line between the nasion and the external occipital protuberance does not correspond to the base of the skull as well as the one chosen.

Relations of the Radiographic Base Line of the Skull.—The following points are found on the same horizontal plane as the base line (Fig. 170): (1) The lower part of the frontal sinus; (2) sphenoidal sinus; (3) apex of the petrous bone; (4) clivus of the sphenoid; (5) glenoid cavity and condyle of the lower jaw; (6) external auditory meatus; (7) jugular foramen; and (8) base of the mastoid process.

The point of intersection at the one-third distance from the nasion is at the zygomatic malar suture and corresponds in the interior with the front part of the sphenoidal sinus. The point at the one-half distance is at the glenoid fossa and condyle of the lower jaw, and corresponds in the interior with either the lower part of the dorsum sellæ or just a little behind it, the apex of the petrous bone. The point at the two-thirds distance is on the mastoid process, towards its posterior margin, and corresponds with the curved portion of the lateral sinus in the interior.

If in the interior of the skull a mesial base line is drawn between the ends of the corresponding base line on the exterior it will be found that the intersecting lines at the one-third and at the one-half distance correspond in both cases, but that the intersecting line at the two-thirds distance on the exterior base line corresponds to a point at the three-quarter distance on the mesial line in the interior.

Relations of the Perpendicular Lines and the Areas defined by them.—The perpendicular at the one-third distance corresponds with three sutures of the skull, the coronal, the squamo-sphenoidal, the spheno-maxillary, in order from above downwards (Fig. 171). It bisects the frontal lobe of the brain, and roughly divides the face from the hairy scalp.

The perpendicular at the one-half distance approximately corresponds at its upper end with the fissure of Rolando, and below the base line with the posterior margin of the ascending ramus of the lower jaw.

The perpendicular at the two-thirds distance bisects the parietal lobe of the brain.

These three lines divide the head into four regions which may be called A, B, C, D, from before backwards.

Region A contains the anterior fossa of the skull with the anterior half of the frontal lobe, the orbits and the facial bones with the exception of the ascending rami of the lower jaws and the palate bones.

Region B contains the body of the sphenoid and the greater part of the sphenoidal sinus, the sella turcica and pituitary body, the palate bones and ascending rami of the lower jaw, the posterior half of the frontal and the anterior part of the temporo-sphenoidal lobe of the brain.

Region C contains the mastoid process, petrous temporal bone, occipital condyles, anterior half of the parietal and posterior part of temporal lobes of the cerebrum, the pons, medulla, and anterior part of the cerebellum.

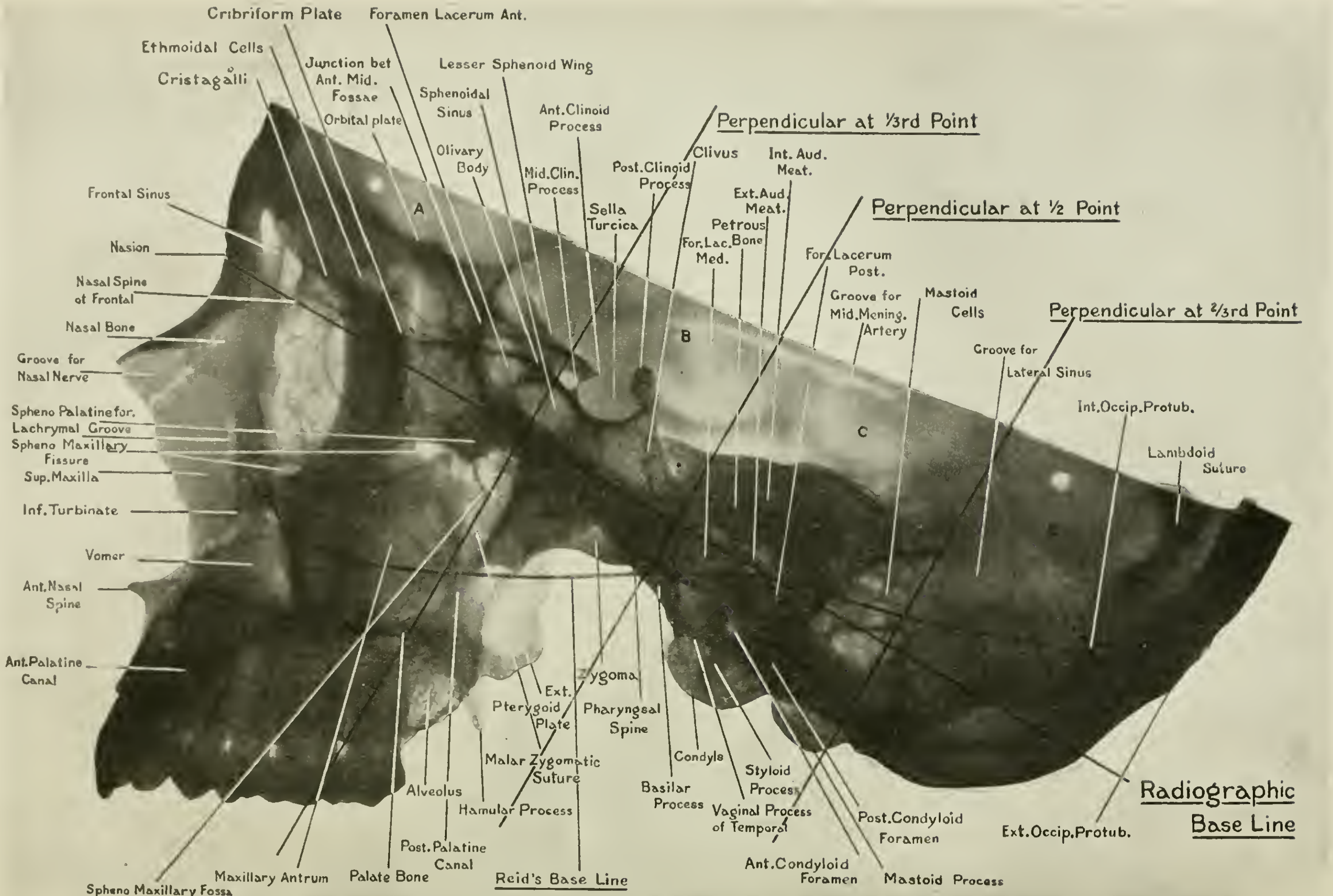


FIG. 170.—Radiogram from a dry skull to show base line and anatomical landmarks. From *Archives of Radiology and Electrotherapy.*

Region D contains the horizontal portion of the lateral sinus, the occipital lobe and posterior half of the parietal lobe of the cerebrum, and the posterior part of the cerebellum.

As an illustration of the use of the system: To radiograph the sphenoidal sinus laterally. The system shows that the base line runs through the sinus, and that it is situated between the intersecting lines at the one-third and one-half distance. The tube is therefore arranged so that its central rays pass through the base line and between the intersecting lines.

The technique necessary in this system of measurement need be only briefly indicated.

The patient may be radiographed with the head in either the vertical or horizontal position, in other words the sagittal suture should be parallel to the plate, a point of importance in order that a region localised on one side of the skull may exactly correspond with the similar region on the other side; for accurate work of this kind a head rest is essential.

Fig. 171.—Figure to illustrate the radiographic base line and its divisions in relation to the skull and brain. (After Cunningham.) From *Archives of Radiology*.

The side to be radiographed is placed next to the plate, the opposite side being made use of for localisation.

When in proper position the tube is centred over the base line of one side, and the two lines will be found to coincide exactly; or if the tube is centred over the perpendicular drawn at the one-half distance, then both perpendiculars at that point on the two sides of the head will be found to coincide.

In the localisation of bullets or shrapnel in the brain this system may be used in conjunction with the cross-thread method of Sir James Mackenzie Davidson. It can also be used in conjunction with the ordinary stereoscopic method, the resulting negative or prints being viewed from the point chosen before the tube was shifted to either side.

In order to facilitate the ready selection of points from which to radiograph the skull the use of a special cassette with mechanical adjustments is advisable.

(1) The Mastoid Region.—Lange, in 1909, described a position which has been generally adopted.

It is an oblique lateral position, the patient lying on the side with the mastoid process resting upon the plate. The rays are directed from above and behind, entering obliquely below the parietal eminence of the side most distant from the plate and pointing towards the mastoid of the opposite side. The axis of the compression cylinder is tilted at an angle of 25 degrees from the plane of the base of the skull (Reid's line) and inclined backwards 20 degrees from a plane passing vertically through both external auditory meata.

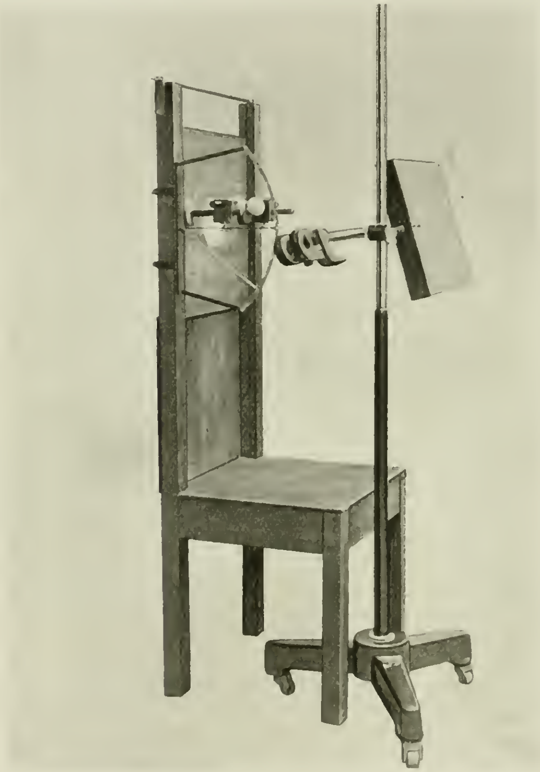


Fig. 172.—Dr. M. Berry's chair for frontal sinuses, etc.

Pfeiffer suggested that the rays may be projected through the vertex of the skull, the patient sitting on a stool resting the chin on the plate; the tube is centred on the vertex of the skull, so that the axis of the rays passes through the skull in the vertical plane at a point 2 cm. anterior to the central point of the external auditory meatus.

Bowen gives an alternative procedure which has the disadvantage of extreme discomfort for the patient; most patients object to this position. The head hangs over the edge of the table to rest upon the plate which is placed upon a stool or other structure at a convenient height; the central ray is arranged so that it may pass through the same vertical plane as in the position recommended by Pfeiffer.

For the examination of the mastoid region a good technique has also been described by Dr. Howard Pirie. The following is the technique he recommends:

Technique.—The patient should lie prone on a firm couch. The head is supported on an inclined plane, making an angle of 25 degrees with the plane of the couch, as shown in Fig. 173. The photographic plate rests on this inclined plane. The head is rotated 90 degrees so that the patient looks directly to his side; this brings the mastoid into contact with the plate. The pinna of the ear is turned forward, so as to obscure the mastoid as little as possible. The source of X-rays is placed vertically above the head, and the perpendicular ray is made to fall on a point 2 inches above the highest point of the pinna. The mastoid on each side must be skiagraphed separately.

The glass of the focus tube should be 9 inches away from the hair. The exposure required will turn a Sabouraud pastille, placed at 2 centimetres from the glass, to one-third of the B tint. A medium hard focus tube (4-5 Benoist), with 30 milliamperes for fifteen seconds from a Snook apparatus, gives a plate which should be fully developed in seven minutes (Ilford plate and developer).

Skiagraphs of both right and left mastoids must be made of every case, as a single skiagraph of one mastoid is of little value. A different focus tube should be used for each mastoid, as it is rarely possible to get one tube to remain constant in vacuum for both exposures. Both focus tubes must, of course, be of the same hardness. This is one of the most important points in the technique—viz. to have two similar tubes of equal hardness and quality. The American-made tubes lend themselves to this better than any others I have used.

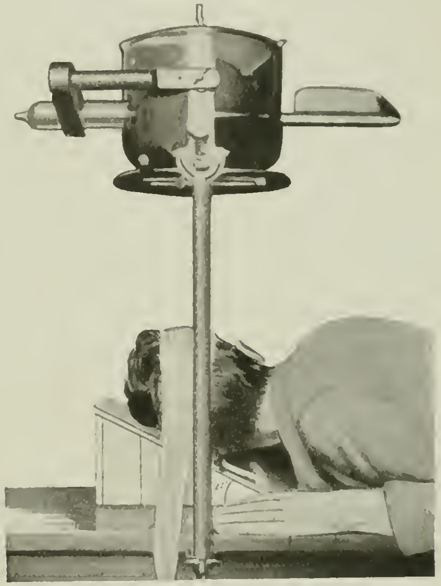


Fig. 173.—Position for radiography of the mastoid region by Pirie's method.

Having secured radiographs of both right and left mastoids, one should place them side by side in a viewing-box, and note any differences. The radiograph should show:

1. The articulation of the lower jaw, and the posterior border of the ascending ramus of the jaw.

2. The auditory canal, placed behind the articulation of the lower jaw, and separated from it by about one-quarter of an inch.

3. The air cells, which form a reticulum extending from the articulation of the jaw backwards. The cells usually appear larger in the lower part, and smaller above. Sometimes they extend forwards above the articulation of the jaw into the base of the zygoma. It should be remembered that the cells extend well behind the limit of the mastoid process.

4. The petrous bone surrounding the auditory canal, appearing as a dense area superimposed on the mastoid cells.

5. The outline of the lateral sinus should be faintly indicated running through the posterior half of the cells.

6. The foramen magnum, appearing as an elliptical opening with part of the first vertebra crossing it.

7. The outline of the pinna of the ear.

Acute mastoiditis shows the following departures from the above description:

1. The air cells are obscured, but can still be faintly seen.
2. The outline of the lateral sinus may be a little more defined than normally.
3. The petrous bone is denser.
4. The whole mastoid region is denser.

When one gets an absolutely normal mastoid on one side, and the other side presents the appearance just described, together with certain clinical signs and symptoms, one is justified in diagnosing acute mastoiditis.

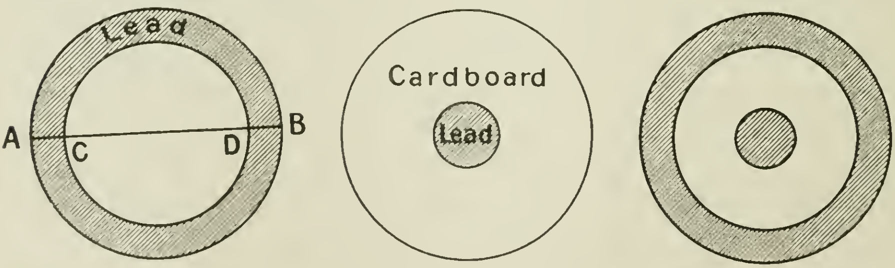
Chronic mastoiditis is very typical in a skiagraph. It presents the following departures from the normal :

1. The air cells are completely absent.
2. The petrous bone stands out as a very dense, roughly triangular, area with its apex pointing upwards and backwards.
3. The posterior border of the petrous bone forms part of a sharp crescent-shaped line. This crescent-shaped line corresponds with the upper and anterior border of the lateral sinus.
4. The lateral sinus is frequently very well shown.

(2) Radiography of the Sella Turcica.—A useful method for the radiography of the sella turcica has been described by Dr. Finzi. The patient is placed upon the couch and the tube centred from below. To determine the exact position two small coins are placed one in each ear. After these are superimposed under the screen, the tube is then moved upwards and forwards 1 inch in each direction, and the radiograph taken. A perfect picture of the area required should be obtained.

There is one objection, however, to this method, and this is the obvious one that the lower coin (assuming the tube to be beneath the table) will cast a larger shadow on the screen than the upper one, and therefore, as both coins are opaque, it is not possible to say when the smaller shadow is exactly in the centre of the lower one, as it should be if the view of the head is to be a strictly lateral one.

To obviate this defect Trevelyan George has substituted a lead ring for the *lower* coin (again assuming the tube to be below the table). This is very simply made by describing two concentric circles on a piece of thick sheet lead and cutting away the superfluous metal. Exact measurements are not essential, as ears differ much in size, but a convenient size is obtained by making AB equal to 20 mm., and CD to 14 mm. (see Fig.), and a convenient thickness of sheet lead to use is $1\frac{1}{2}$ mm.



Instead of the *upper* coin a circular lead disc, cut out of the same sheet of metal, is used, a suitable diameter being 7 mm.

Now, it is of the utmost importance that the two articles, the ring and the disc, be placed symmetrically in the auricles, and as they differ in external diameter, this raises a difficulty. In order to get over this, the diameter of the disc is artificially increased to that of the ring, *i.e.* to AB, by em-

PLATE XIII.—Negative and Positive Pictures of a Skull from a Living Subject.

Showing anatomical landmarks. The accessory air sinuses are well seen.

bedding it in a circular hole of the proper size cut in a piece of cardboard of about the same thickness as that of the lead, and trimming the cardboard to the necessary size and shape. To keep the disc firmly in its place within the cardboard, two circular discs of thinner cardboard are cut with diameters equal to AB, and cemented with glue or seccotine one on each side of the compound disc of lead and cardboard. The result is a disc which looks as if it were made entirely of cardboard, but which really contains the lead disc embedded in a central position in it. Wood or other partially transparent materials can of course be used instead of the cardboard. A coating of " new skin " renders the disc waterproof, and it can then be washed after each case.

When radiographing particular areas of the skull, the diaphragm should be shut down to the smallest possible size, or if the tube is used overhead a small extension tube should be inserted between the tube and the patient. Pictures obtained in this way will be found to give much finer detail than those taken with a wide diaphragm. It is important to note that in radiographs of the skull as much detail as can be obtained is desirable.

(3) The Examination of the Frontal Air Sinuses.—Two methods may be employed: (*a*) a lateral view of the skull, showing the air sinuses in profile; (*b*) antero-posterior, the plate on the front of the skull and the tube behind. A direct antero-posterior view does not show the sinuses at all well, the overlapping of the shadow caused by the occipital and temporal bones obscuring the detail in the frontal and accessory sinuses. There are two routes by which the rays may be passed through the back of the skull. (1) The tube may be centred below the bony mass formed by the occipital protuberance: the rays still have to traverse the thick parts of the base of the skull. (2) A better method is to place the patient face downwards on the photographic plate, the latter being placed at an angle of 25 degrees. The tube is centred well in

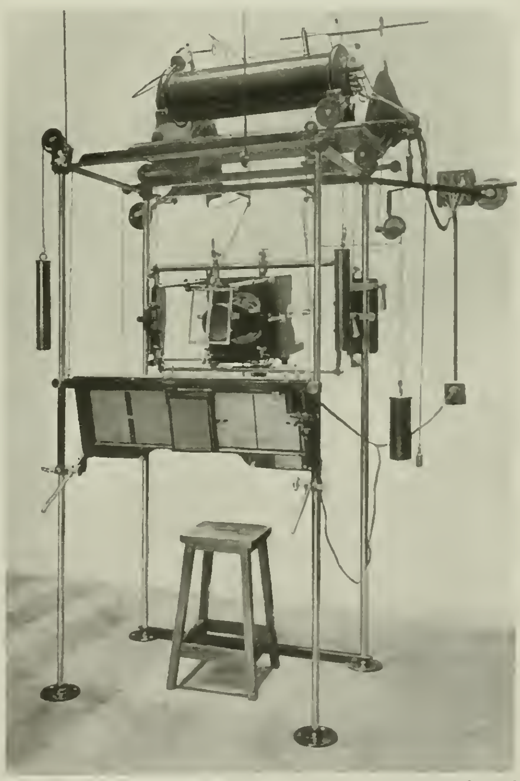


Fig. 174.—Arrangement of apparatus for radiography of the orbit and accessory sinuses. Fitted with quick-changing stereoscopic movement. (F. Butt & Co.)

front of the occipital protuberance, and an oblique though somewhat distorted view is obtained which shows the frontal air sinuses well. The Plates showing frontal air sinuses, taken by this method, illustrate the points to be examined.

(4) The Sphenoidal Sinus.—The lateral position gives an indication of the extent of the sphenoidal sinus so far as depth is concerned, but it is impossible to judge the size of the right or left side from such a radiograph. Stereoscopic plates will, however, aid greatly in estimating the size and extent of the sphenoidal sinus. The postero-anterior projection affords

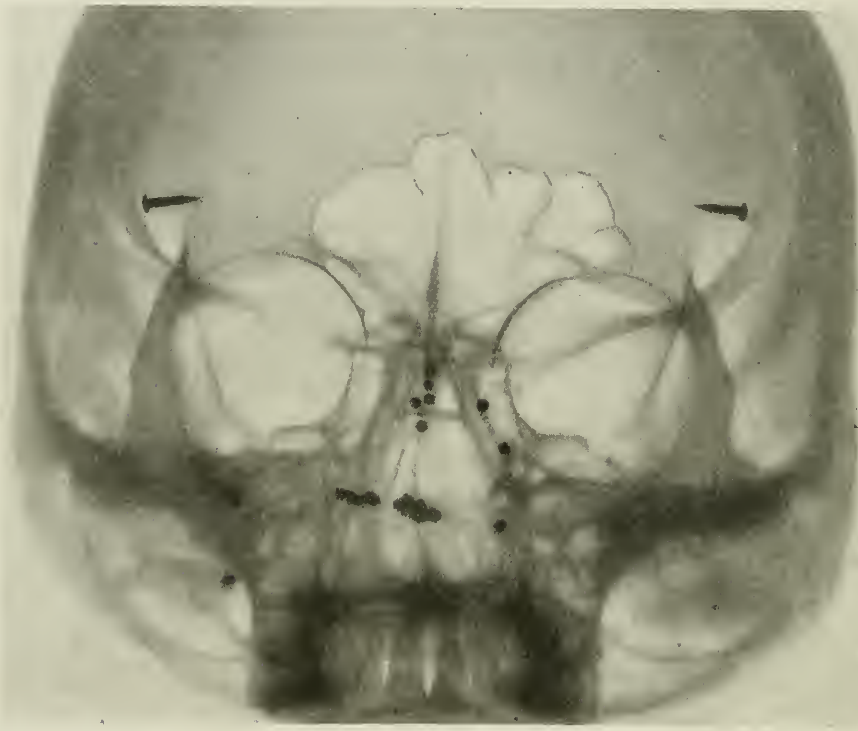


FIG. 175.—The accessory nasal sinuses taken at an angle of 25°. This angle gives a good general view and is the best for the sphenoidal sinus. (By H. Martin Berry, M.D.) From *Archives of Radiology and Electrotherapy.*

very little assistance. There are, however, other positions which are helpful.

Pfahler recommends an oblique position for both sides of the head—and that in all cases both sides should be done for comparison. The patient's head is placed so that the brim of the orbit is resting upon the plate. The tube is placed at a distance of 22 inches from the plate, and in such a position that the central ray enters the opposite parietal region about 2 inches posteriorly and $1\frac{1}{2}$ inches above the external auditory meatus, and passes towards the centre of the orbit.

If the position is correctly estimated the optic foramen will occupy the centre of the orbit, and to the outer side will be seen the sphenoidal fissure.

Towards the median line is projected the sphenoidal sinus, anterior to the optic foramen ; above this will be seen the upper brim of the orbit and above the orbit the frontal sinuses.

In radiography of the skull there are various positions which are useful for the production of radiograms of value in diagnosis. Screen methods are useful in two directions, (1) for the selection of the best position in which to secure the most useful picture of the skull, (2) for diagnosis—direct diagnosis by the screen method is not generally used though it may at times be extremely useful.

Of the radiographic methods advocated there are several good techniques which are valuable. Some require most elaborate instrumentation and

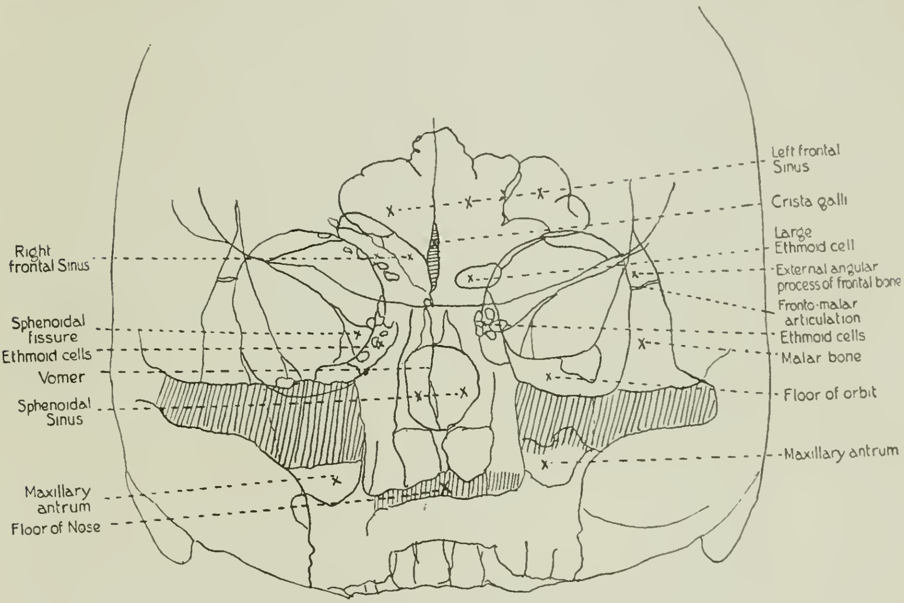


FIG. 176.—Diagram illustrating the anatomical landmarks in Fig. 175.

produce uniformly good results ; others are simpler and most useful for ordinary work. Whichever is employed it should be the endeavour of all operators to approximate to a standard in position so that results may be comparable. Finzi and Hett advocate the supine position on the X-ray table, and make use of the screen for finding the best position.

Martin Berry has exhaustively dealt with the positions for sinus work, and has indicated what are in his opinion the best positions. He has introduced a chair fitted with mechanical adjustments which enable the operator to repeat the exact position at a subsequent exposure (see pp. 197 and 202). This is an important step towards the standardisation of positions.

He recommends the following position for the satisfactory demonstration of the accessory sinuses.

For the postero-anterior view he advocates that the angle will require to be varied for the particular sinus which calls for investigation.

An angle of 25 degrees gives a good general view and is the best for the sphenoidal sinus, as its shadow is then free of the most serious obstructions. Large angles give a better view of the ethmoidal region and the roof of the orbit, while small angles are used to show the lower part of the maxillary antra.

Of the simpler methods there are several which, while not involving the use of elaborate mechanical contrivances, enable the operator to produce good diagnostic results with unfailing constancy. These are usually carried out with the patient on the table.

To obtain a picture of the two sphenoidal sinuses side by side, a plate is placed under the chin and the tube centred over the vertex at right angles to the plate. A film placed in the mouth well backwards under the hard and soft palate will give a similar picture. For the lateral view the patient may lie on a couch with the plate under the head and a compressor extension tube brought down on to the head; this serves the double purpose of fixing the head and cutting off secondary radiations from the tube. In all cranial work care must be taken to see that the long axis of the tube is parallel with the plate, and that the anti-cathode of the tube is accurately centred in the tube-box before the tube is brought into position. For general purposes a central position of the tube is all that is necessary, the anti-cathode being over the centre of the plate, and the base line of the skull corresponding as nearly as possible with the centre line of the plate in its longest diameter.

Undoubtedly the best method of all for examination of the lateral position is the stereoscopic, because it enables one to examine the skull in relief.

In the single picture it is necessary to have the skull in the exact lateral position so that there shall be no overlapping of the two sides of the skull.

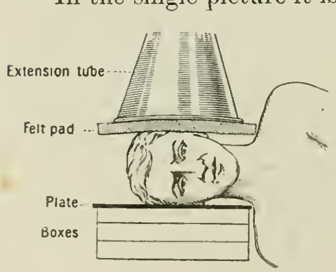


Fig. 177.—Radiography of the skull: lateral position, showing method of adjusting the plate and extension tube.

For the production and maintenance of the true lateral position an arrangement whereby the head can be supported is necessary. Hickey's wooden pillows are useful; these are shallow wooden boxes which can be laid one upon another until the desired level is obtained. They should be large enough to take the size of plate in use, 12 × 10, and a flat plate changing cassette is a useful addition to the set.

Technique for Lateral View of the Skull.—The patient may either sit up in a chair or lie on the couch; the latter position is the more comfortable, and it is easier to immobilise both patient and plate.

The central ray should pass through the head in a transverse plane; the plate should be at right angles to the central ray and parallel with the sagittal plane of the head. The tube holder is arranged so that the central ray passes through at a point 1 inch above and 1 inch in front of the external auditory meatus.

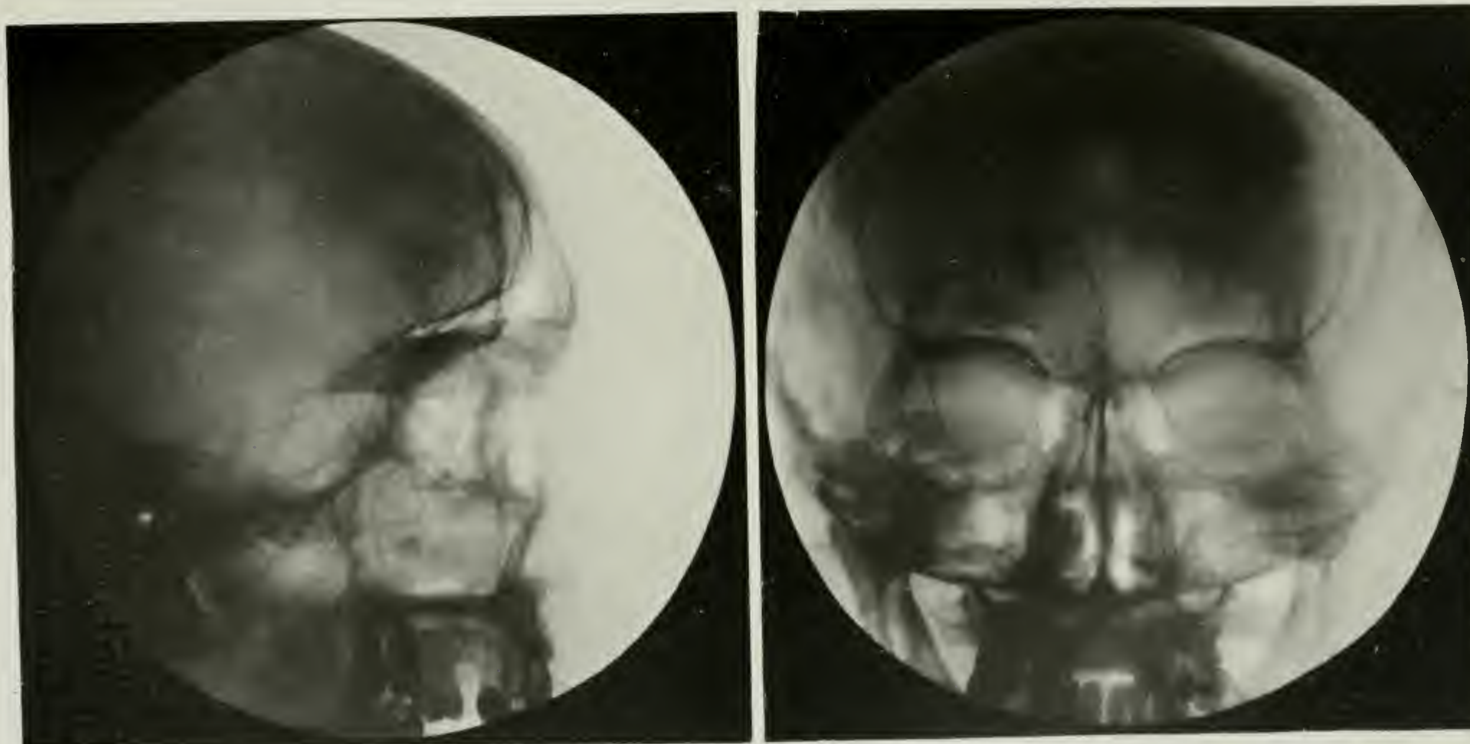


PLATE XIV.—LATERAL AND ANTERO-POSTERIOR VIEWS OF A SKULL TO SHOW ORBITS, FRONTAL SINUSES, ETHMOIDAL SINUSES, SPHENOIDAL SINUSES, AND MAXILLARY SINUSES.

There is a minute foreign body in frontal sinus.

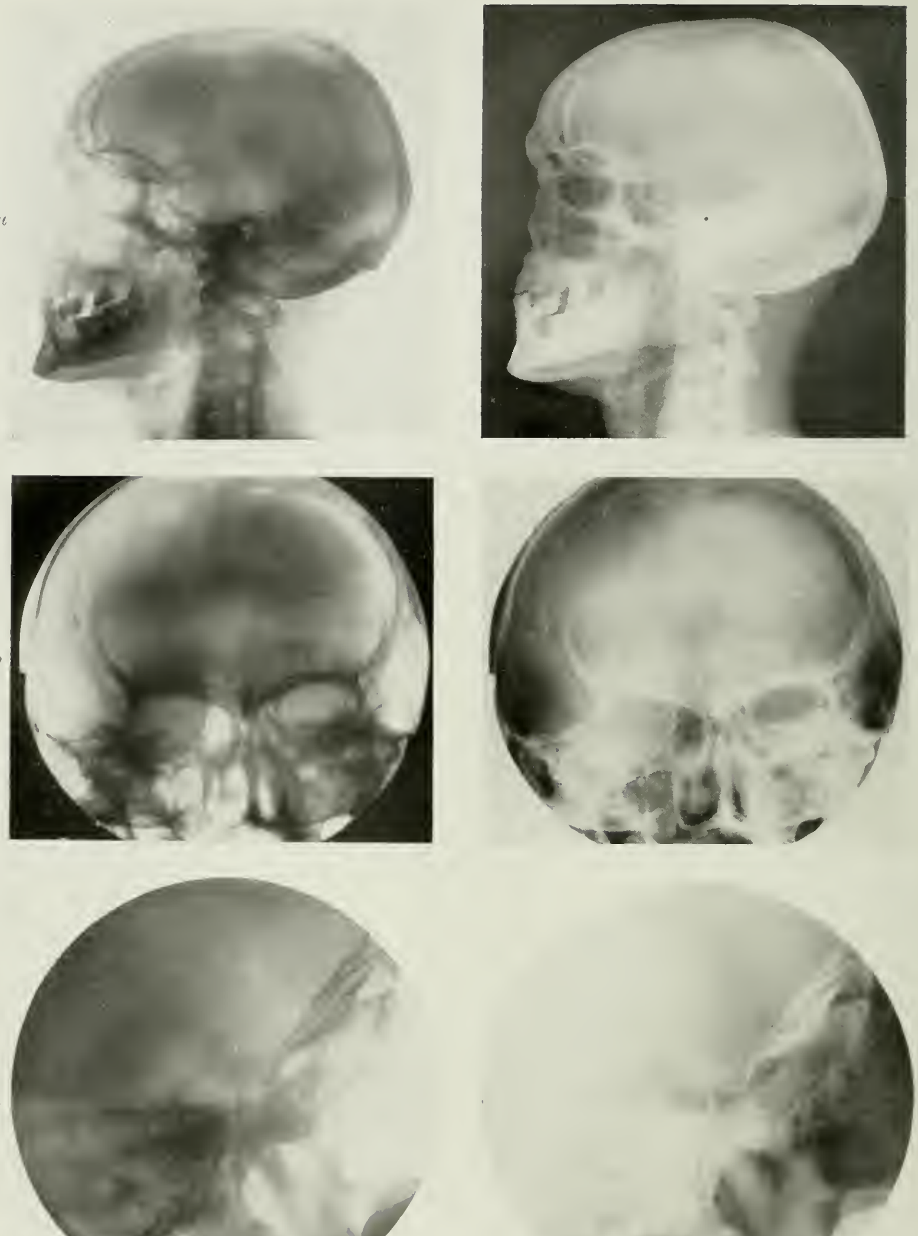


PLATE XV.—NORMAL SKULLS.

a, Lateral view of normal skull, showing frontal sinuses, sphenoidal sinuses, sella turcica, temporal bones, cervical vertebræ, and lower jaw.

b, Antero-posterior view of adult skull, showing frontal sinuses, orbits, nasal fossæ, antra, etc. Frontal sinus on left side is opaque.

c, Lateral view of skull to show the sella turcica, articulation of spine to skull; the temporo-maxillary articulation on one side is well seen.

In the postero-anterior position a convenient arrangement is to have a wedge-shaped structure large enough to take a 12 × 10 plate.

The surface is set at an angle of 25 degrees to the base.

The patient's forehead rests upon the surface of the wedge.

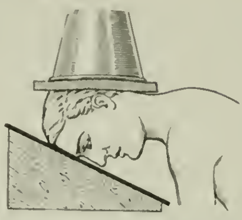


FIG. 178. — Radiography of the skull: Postero-anterior position.

The focal point of the rays is considerably above the occipital protuberance.

Waters and Waldron have suggested a new position which appears to give all the necessary particulars with great ease in production. In their position it is possible to obtain reliable information regarding the frontal ethmoidal and maxillary sinuses without the superposition of any shadows of the petrous temporal bones.

The patient lies face downwards on a horizontal table with the chin resting on the plate or cassette containing the plate. A compression diaphragm of 18 cm. in depth is screwed down tightly upon the occiput, with a felt pad 2 cm. in thickness interposed. Approximally an angle of 45 degrees is formed by the vertical axis of the head with the plate.

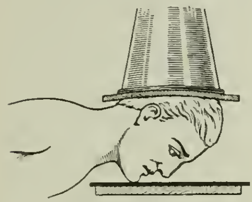


FIG. 179.—Radiography of the accessory sinuses. Position recommended by Waters and Waldron.

Three points are essential in order to obtain reliable radiographs of these regions.

(1) The chin must always touch the plate.

(2) The long axis of the tube should be parallel to the plate.

(3) The nose of the patient should be from 1 cm. to 1·5 cm. from the plate, and must in no case touch it.

In the positions described, the chief objection to their use is the difficulty of ensuring complete immobility during the exposure; head-rests can readily be added to the plate-holder which will enable the operator to maintain the fixed position as long as is desired.

With a convex-shaped face the nose should be arranged at 1 cm. from the plate; in the concave-shaped face the distance of the nose from the plate should be increased about ½ cm. with the tube still remaining parallel to the plate.

The distance of the nose from the surface of the plate, with the long axis of the tube parallel to the plate, enables us to produce radiograms of the accessory sinuses, without projecting the basal structures of the skull into the maxillary antra.

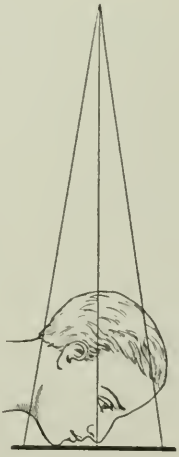


FIG. 180. — Radiography of the skull. Diagram showing direction of rays.

In order, if possible, to standardise the technique in radiography of the skull, the author, in collaboration with Dr. R. W. A. Salmond, worked out the preliminary stage of a system of topography for use in cranial radiography (see pp. 198 to 201).

The normal skull taken in the lateral position (Plate XV. Fig. *a*) shows all the important structures at the base of the skull; the three levels are well shown, and the various air sinuses are distinctly seen, notably the frontal air sinuses. Taking the bones of the skull from before backwards, one sees the orbital plate of the frontal bone, the anterior clinoid process, the sella turcica, the posterior clinoid process standing well in relief; extending backwards, the petrous portion of the temporal bone appears as a denser irregular shadow, and, immediately behind, the mastoid air cells are prominently shown. Then, at the posterior portion, the well-marked depression formed by the occipital bone is shown. The thickness of the bony wall of the section of the skull shows the inner and outer tables with the bony structure between them.

In the region of the neck the cervical vertebræ are shown in profile, the styloid process extending downwards and forwards between the cervical vertebræ and the descending ramus of the lower jaw. The zygomatic arch is seen extending forwards on the lateral aspect of the face. The superior maxilla gives an irregular shadow and the anterior shows a clear space, the nasal bones are faintly outlined in profile, and the lower jaw is also shown in its lateral aspect.

(5) The Lower Jaw is an important bone, and rather difficult to demonstrate satisfactorily. It may be shown by several methods : (*a*) Showing the whole of the bone in a skiagram of the face. (*b*) The best position in which to show the lower jaw is to place the side to be examined upon the plate, tilt the head upwards, and to angle the tube so that the central ray passes between the two sides of the mandible, the side lying upon the plate is shown with practically no loss of detail from superimposition of the other jaw. The same result can be obtained by first centering the tube over the angle of the jaws for the direct lateral position, then displace the tube downwards towards the feet for about 2 inches. (*c*) Portions of the bone may be demonstrated by placing a film inside the mouth against the part of the bone it is necessary to show, and using the focus tube outside. The picture then obtained is a small one, but quite large enough to show a fracture, an abscess, or disease or damage to a tooth and its socket. The temporo-maxillary articulation of either side can be satisfactorily shown by centering the tube behind and a little below the angle of the jaw on the more distant aspect from the plate. The most satisfactory method of showing injuries in the region of the upper or lower jaw is undoubtedly the stereoscopic, the advantage being that by this method the parts may be viewed in the stereoscope from either side by changing the plates, *i.e.* in one position the film surface is outwards and in the second the glass surface of the plate is outwards. It is possible to form an accurate opinion regarding the positions of the bones.

Plate XV. Fig. *b* shows the chief bony points of the skull and face taken from the antero-posterior position. The plate was placed on the face, with the focus tube behind. The orbits are well marked, and the nasal cavities show a considerable amount of detail, which is of great value when one has to consider the possibility of fracture in these regions. The antrum of

a

b

c

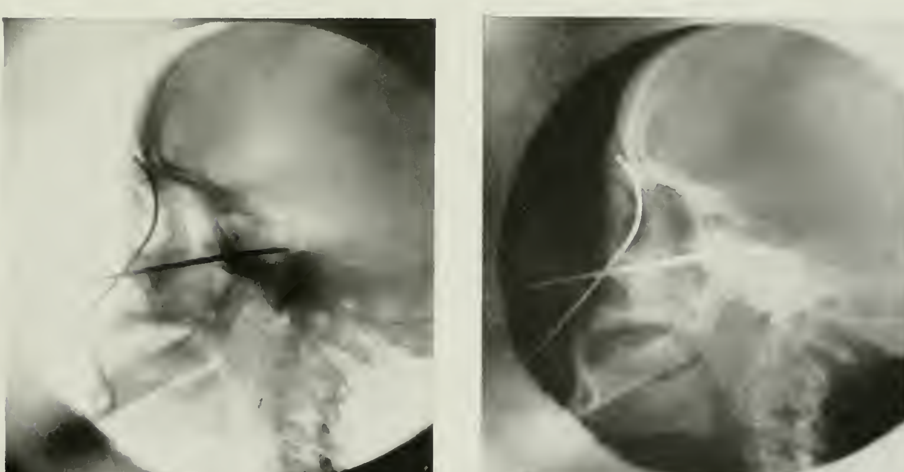


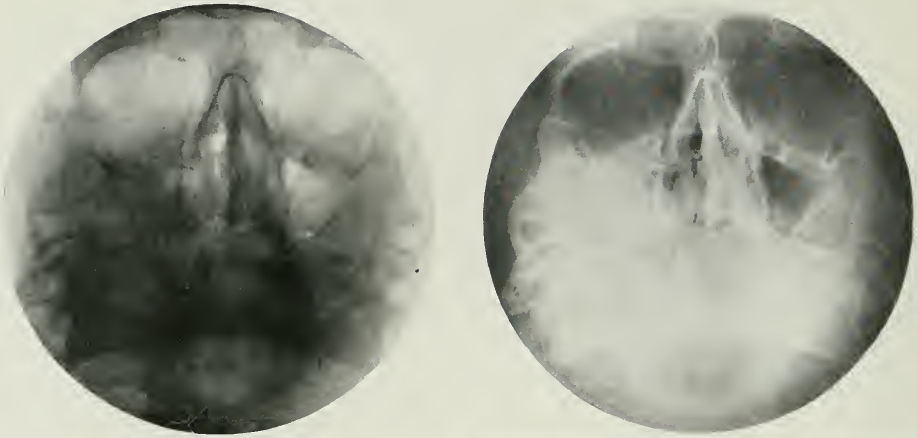
PLATE XVI.—NORMAL SKULLS.

a, Skull showing several pieces of metal in face. The sella turcica is particularly well shown.

b, Mid area of skull; a line has been placed on points giving the radiographic base-line; the line runs through the base of the sella turcica (dry skull).

c, Lateral view of skull in living subject; probes have been placed in the frontal and sphenoidal sinuses.

a



b

c

PLATE XVII.—SKULLS SHOWING DEPARTURES FROM THE NORMAL.

a, Opacity in right antrum. (Radiographed in position described by Dr. Waters.)
b, Skull in a child, showing moulding of the cranial bones resulting from intracranial pressure.
c, Skull from a case of tumour of the brain, situated at the sella turcica; the detail in the region is lost.

Highmore is clearly defined, the zygomatic arch stands out prominently, the lower jaw is thrown out in relief, and behind there is a distinct picture of the mastoid portion of the temporal bone with the air cells.

Plate XV. Fig. *c* shows a small and more distinct view of the central portion of the bony parts of the head. The points to observe are the levels of the bone of the skull in relation to the exterior, the clinoid processes with the sella turcica between, the relation of the chief sutures to the various levels, and the well-marked grooves for blood-vessels in the inner table of the skull. A clearly defined shadow is thrown by the pituitary body situated in the sella turcica. The cervical vertebræ in relation to the bone of the skull show up well. The condyle of the lower jaw, situated in its articular cavity, is also evident, and a fairly good idea of the general contour of the latter.

(6) The Examination of the Mouth, and especially the Teeth, is one which calls for special attention. The general outline can be obtained by plates placed on the exterior, the tube being angled to prevent overlapping of the shadows produced by the two sides. Better results can be obtained when films are placed in the interior of the mouth against the area required, the tube being centred over the film from the outside. A suitable mouth gag may be used ; this possesses the great advantage of preventing movements during the exposure ; a piece of cork or a towel rolled up tight is also very efficacious when other appliances are not at hand. The stereoscopic method is invaluable in the examination of the teeth.

Special appliances have been devised for the retention of the film in the mouth. A suitably shaped cork is provided with a slot, into which various rectangular plates of metal are slipped. These metal plates are soft, and can be bent into any curve to suit the contour of the mouth, and thus secure a close contact. The cork is gripped in the mouth by the patient, it being obvious that this method enables the film to be held in any position inside the mouth without any further device or support.

The films are wrapped up in paper as usual, with a small loop of paper left at the back, which is slipped over the metal plate, so that any curve to which the plate is bent also carries the film with it.

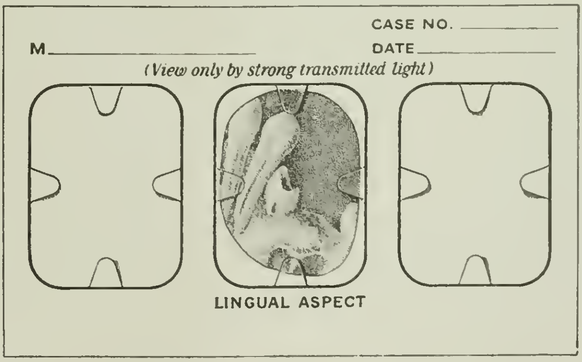


FIG. 181.—Representing a celluloid mount with one dental film in position.

The films when dried require to be viewed in a transmitted light. Celluloid mounts with cut-out tongues to grip the films can be obtained, and these provide a convenient method of examining the films.

The Cervical Region

The best positions in which to radiograph this area are : (1) The antero-posterior, and (2) the lateral. The antero-posterior is comparatively easy in the lower two-thirds. When the patient is placed with the posterior aspect on the plate and the tube centred over the middle of the plate, a view is obtained of the cervical vertebræ and the upper dorsal, the apices of the lungs coming into the picture, as do also the sternal ends of the clavicles and the manubrium sterni. The upper cervical vertebræ are obscured by the basi occiput and the lower maxilla.

FIG. 182.—Upper cervical region, antero-posterior view. Taken with plate behind and an extension tube in front of the open mouth.

Should it be necessary to obtain an impression of the first three cervical vertebræ, other methods must be adopted. The base of the occiput and the first and second cervical vertebræ may be examined by placing a plate on the posterior aspect; and by using a small extension tube, with the mouth opened to its widest extent, a good radiograph may be obtained which should show the condyles of the occipital bone, the odontoid process of the axis, the atlas, and the third cervical vertebra.

FIG. 183.—Normal cervical and upper dorsal region showing the sterno-clavicular articulation. This position is useful when examinations for cervical ribs have to be made.

The lateral view of the cervical area shows the whole region from the occiput down to the upper dorsal vertebræ. This is a good method for

a

b

c

d

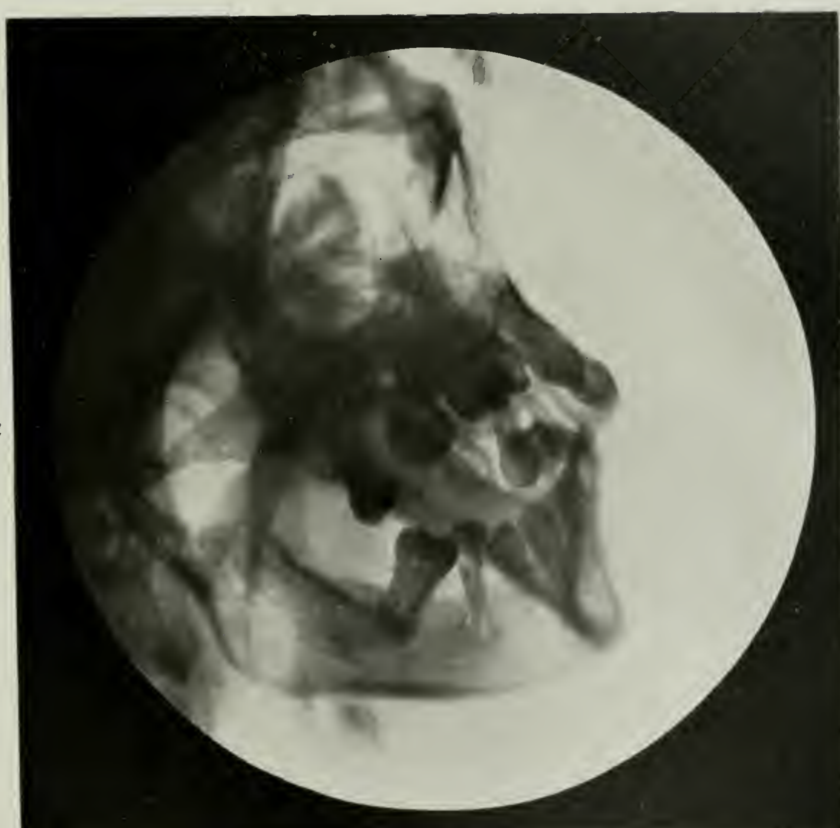
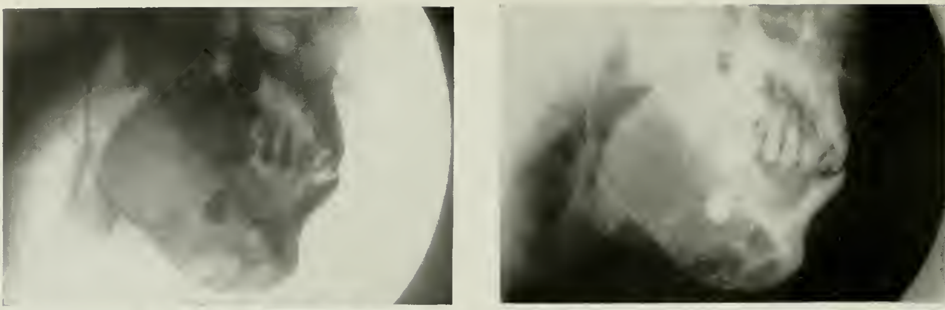


PLATE XVIII.—DENTAL FILMS AND NORMAL JAW.

a, *b*, and *c*, Reproductions of radiograms of teeth obtained with film in the mouth.
d, Lateral view of upper and lower jaw to show teeth in left lower jaw. The inferior dental canal is well seen.

a


b


c

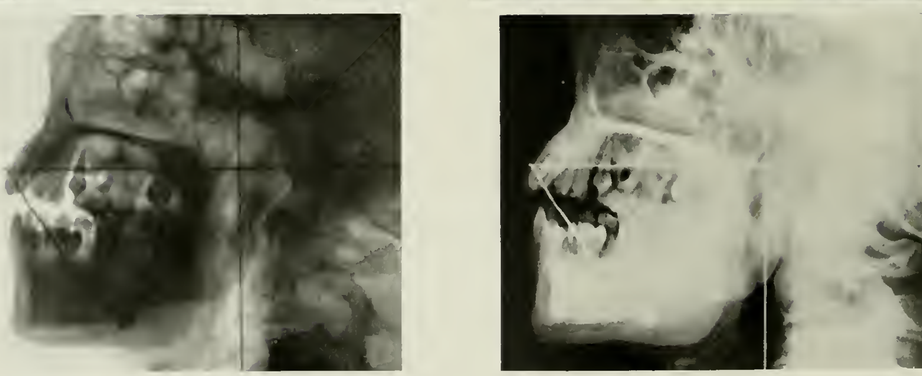

d


PLATE XIX.—LOWER JAW AND CERVICAL REGION.

a, Dentigerous cyst in lower jaw (buried tooth).
b, Fracture through ramus of lower jaw.
c, Showing good detail in soft parts, absence of teeth, calcified cervical glands.
d, Calculus in submaxillary duct, probe leads to calculus. (Radiogram by Dr. Harvey.)

ascertaining the condition of the bodies of the cervical vertebræ, the integrity of the spinal canal, and the presence of abnormalities of the region. The presence of cervical ribs can best be shown by the antero-posterior position.

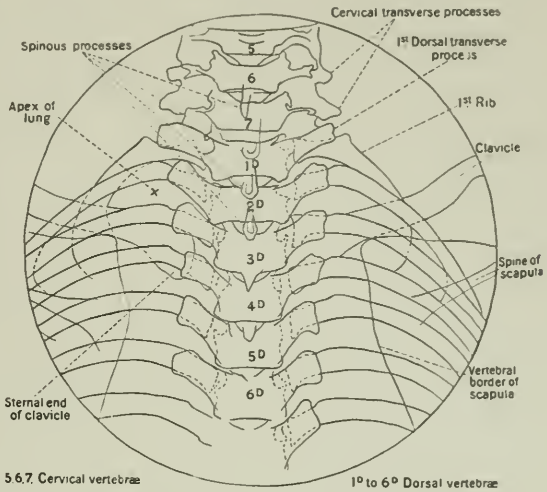


FIG. 184.—Diagram to illustrate the anatomical points in Fig. 183.

The cervical region has been partially shown in Fig. 182, but it is necessary to illustrate this particular region fully, for it is here that the difficulty of showing a fracture or dislocation may be very great, and in some instances impossible.

An antero - posterior view of the neck region is not a very satisfactory one, because of the superimposing of the occipital region and the lower jaw. In cases where it is desirable to show the atlas and axis, and the articulation between the former and the occipital bone, it is necessary to take the skiagram through the open mouth, as described in detail above. The resulting picture is necessarily small, but large enough to include the parts desired.

FIG. 185.—Radiogram showing presence of cervical rib on left side.

The position usually taken is the lateral one, with the head rotated towards the plate. It is then possible to get a fairly good outline of the seven cervical vertebræ and the adjacent portions of the base of the skull. The bodies of the cervical vertebræ are readily shown, but to get accurate outlines the head must not be moved to either side.

The Upper Extremity

Normal focus point.—M'Kendrick, in a valuable paper published in the *Archives of Radiology*,[1] defines "a normal focus point," which may

[1] "Radiography of the Normal Parts," by Archibald M'Kendrick, F.R.C.S.Edin. (*Archives of Radiology and Electro-Therapy*, January 1916).

be used for the joints of the extremities. It is given as "24 inches (60 centimetres) directly over the centre of the joint, with the centre of the joint in the middle of the plate." This is an extremely useful position for all joints, and should be adhered to whenever possible.

The Examination of the Clavicle.—The clavicle requires to be considered in its whole length. Either extremity will appear in radiographs of the shoulder and of the thorax. The external end has frequently to be examined for displacements and injuries. The acromial end of the clavicle is seen in the several plates illustrating the shoulder-joint.

Examination of the Shoulder-joint.—The shoulder-joint calls for minute description. It is frequently injured, and should be carefully examined in all cases of suspected injury to that region. It is usually examined in the antero-posterior position, first with the plate on the posterior aspect of the joint with the tube in front, and then with the plate placed on the anterior aspect with the tube behind. A third position may be employed. A plate is placed upon the upper surface of the shoulder, including the clavicle to the root of the neck, the arm is abducted to the fullest extent, the tube is centred for the axilla, and the rays projected upwards towards the plate. It should always be examined in the first two positions, if one is to demonstrate an injury in the shoulder-joint. The anti-cathode should be centred as nearly as possible over the coracoid process. An extension tube should be used, and slight pressure applied to the part. The pictures obtained by these two positions differ in several points of detail, the differences being readily seen when the two radiographs are compared. The anatomical points seen in the pictures should be—(1) the head of the humerus; (2) the glenoid cavity; (3) the axillary border of the scapula; (4) the coracoid process; (5) the acromion process; (6) the acromial end of the clavicle. It is usual in such examinations to have the arm by the side. Supplementary skiagrams can be obtained by extending the arm out from the side or carrying it directly upwards in line with the long axis of the body. When it is necessary to examine the tuberosities the arm may be rotated in the direction necessary to show either one. Should the axillary border be suspected, the arm should be carried upwards and forwards and rotated outwards, so as to bring the body of the scapula away from the trunk.

Plate XXI. Fig. *b* shows the appearance of the parts when the plate is placed on the anterior aspect of the joint.

The acromion process is best shown when the plate is placed on the posterior aspect of the joint, with the tube in front, it being then possible to demonstrate the whole of the process and the spine of the scapula, while the infra- and supra-spinous fossæ can also be shown in their entirety. The coracoid process is well seen in all of the shoulder negatives, and changes in its position can be shown, fractures being readily demonstrated.

When fine detail is necessary, and an injury is known to exist in the region of the coracoid process, a small picture should be obtained, an extension tube being centred over the process, and the plate being either on the posterior or anterior aspect of the joint. The greater tuberosity of the humerus will be clearly shown. Its position and appearance will vary with the position of the shaft of the bone at the time, as regards rotation outwards or inwards. With the arm abducted and carried over the head, the shoulder-joint alters considerably in appearance. The head of the humerus and the glenoid cavity are well demonstrated, and the coracoid process is also well seen.

The spine and body of the scapula are often investigated for evidence of fracture or tumour. The bone shows well in any of the usual positions, but if the vertebral border is under inspection, it is necessary to take a plate with the patient lying on it, and the arm abducted and carried upwards towards the head.

The Elbow-joint.—Four positions are available in this joint, and each may be modified by the position in which the limb is placed at the time.

(1) Antero-posterior, with plate on the front of the limb.

(2) Postero-anterior, with plate on the back of the limb.

(3) Lateral internal, with plate on the inner aspect of the joint, the arm being either flexed or extended.

(4) Lateral external, plate on outer aspect of the joint, the forearm flexed or extended.

Good pictures of the head of the radius and its articulation can be obtained by slightly flexing and pronating the forearm.

The Radius and Ulna should always be taken in two positions: (1) lateral, (2) antero-posterior.

The Wrist-joint must always be examined in two planes, the antero-posterior and the lateral. In both positions the tube is centred over the carpus. It is a good plan always to have both wrist-joints on one plate when examining for injury or disease, as it is often helpful to be able to compare the injured joint with the healthy one. Compression of the limb may be effected by using a long extension tube, pads of lamb's wool being applied over the part, or sand-bags may be used to steady the limb.

Metacarpal Bones and Phalanges.—These frequently call for careful examination. Antero-posterior and lateral pictures may readily be obtained, but lateral pictures of the middle metacarpal bones are very difficult to obtain. The hand is placed obliquely on a plate, and the tube directed well in front of the middle line. The picture is somewhat distorted. Lateral views of the phalanges can be procured by placing a plate between the fingers.

The Bones of the Chest

The Clavicles may be examined in their entire length, or in sections when the shoulder or upper thorax are in the picture. The patient lies upon a couch with the plate on the front of the chest, and the tube is operated either from below or from above, whichever is the more convenient.

The Sternum has often to be examined, the position in which it is usually taken being from behind forwards. The picture is usually confused by the shadows of the mediastinum and spinal column. An oblique lateral view of the thorax enables us to examine the whole of the sternum with its articulations. The picture is naturally somewhat distorted, but nevertheless a good idea may be obtained of its condition, injuries and tumours being readily shown. The ribs can be shown in these positions, the lateral position showing the ribs in their entirety.

The Dorsal Spine

Two methods are used here : (1) an antero-posterior, with the plate on the posterior aspect of the spine ; (2) a direct lateral view. The latter may be obtained by placing the plate on one side and the tube on the other, the arms being extended above the head, to get rid, so far as is possible, of the shadows of the scapulæ. The bodies of the vertebræ are then well seen, as is also the posterior portion of the column with the transverse process, the laminæ, and spines of the vertebræ. The spinal canal can also be seen in the plate.

In taking the antero-posterior view, it is well to have the tube a good distance away from the plate, the greater the distance the better being the detail shown in the bones. The exposure has to be proportionately prolonged, and if the tube is soft a longer exposure is further necessary. In examining the spine of children for curvature, etc., the author obtains good pictures by placing the tube four or five feet from the plate.

Stereoscopic radiographs should always be taken of these spinal cases, as much more detail can be shown when they are examined in a stereoscope. This method is most useful in extensive caries of the spine when there is considerable deformity, as the picture is sharp, and fine changes in the bones can be detected. When the spine alone is required the diaphragm of the tube box should be closed down in order to get a long, narrow, slit-like aperture ; this ensures better detail in the parts required.

The Lumbar Spine

This is radiographed in the antero-posterior position, from the lower dorsal to the sacrum, by using a large extension tube with compression of the abdominal contents. It is an advantage in all positions of the spine, thorax, and abdomen, to diminish the movements of the parts as much as possible. The methods of compression employed are various. If working from below, it is an easy matter to have some simple form of compressor attached to the upper aspect of the couch. An air-cushion is placed between the patient and the couch to compress the abdominal contents. When using the tube above the couch, the compression may be obtained by fastening stout linen bands to the couch, carrying them round the patient, and fixing on the opposite side. A long extension tube may be attached to the tube-holder, and fixed down on the patient by a mechanical device. These are all matters of detail which can be arranged to suit the individual worker, but whichever method is employed there can be no question of the great advantages of compression.

The Pelvis

This region often requires most careful examination for injuries, disease, or for the presence of calculi in the ureter or bladder. The positions are again two, antero-posterior and postero-anterior, both being useful. To get fine detail of the sacrum an extension tube is used, and it should be pressed well down into the pelvic cavity. The whole pelvis, with the heads of the femora and the acetabula, can be obtained by using a large plate behind the patient, or by placing the patient on the anterior surface with the plate underneath, the tube being placed above the posterior aspect of the patient. For the examination of the coccyx a small extension tube should be used, and the tube tilted forward into the cavity of the pelvis, the plate being placed on the posterior aspect beneath the patient.

The Lower Extremity

The bones of the pelvis are seen in most of the radiographs taken for the bladder and ureters. The sacrum is readily shown by putting a plate beneath the patient, and using a compression tube from above. In large pictures of the region the acetabula with the head of the femur are well shown.

When the two joints are required for comparison, a good method is to radiograph the lower pelvis, centering the tube just below the symphysis pubis. Good detail is obtained of the head of the bones, and a good outline of the acetabulum.

The iliac bones, which often require to be radiographed for fracture, tumour, etc., may be examined in two positions : (1) with the tube centred over the middle of each bone, from the front. (2) The plate on the anterior aspect, the tube being centred on the posterior aspect of the hip-joint, or a little above it.

The Hip-joint is probably one of the joints most frequently examined. Two positions are available :

(*a*) The posterior, when the plate is placed below the patient and the tube centred over the head of the bone.

(*b*) The anterior, with the plate on the front of the joint and the tube centred behind.

Both are useful, and either may give valuable information. The important point is to make sure that good detail is obtained. This joint is the most difficult of all the joints from which to obtain good radiographs. When a view of both joints is required for purposes of comparison, the plate is placed behind and the tube centred above the symphysis pubis.

A third position, described by Dr. P. M. Hickey, is worthy of mention. In exceptionally favourable cases it will be found useful. His technique is as follows :

The patient lies upon the side to be examined, the thigh is flexed until it forms a right angle with the long axis of the body. The plate is placed under the affected side and the rays directed from above downwards, with the tube in front of the patient, so that the central rays are forming an angle of twenty to twenty-five degrees, passing through the great trochanter. The patient's back is supported by long sand-bags, and the femur under examination is immobilised by other sand-bags. The other leg is preferably raised from the table and supported in an easy position by pillows. This technique cannot be employed in cases where pain or disability prevents the flexion of the femur.

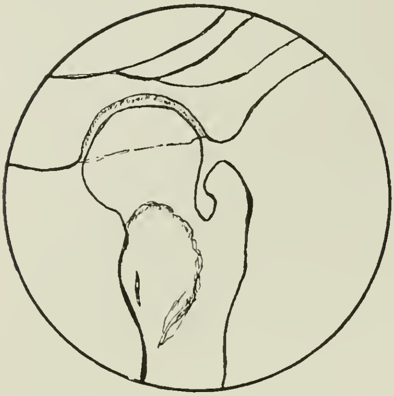


Fig. 186.—Lateral view of the upper end of femur, as seen in the third position.

However obtained, a good radiograph should show the head of the femur, the cotyloid notch should be visible, the rim of the acetabulum should be seen superimposed over the head of the bone, and in normal joints the interarticular space should be shown. The picture should include the greater and lesser trochanter and the upper third of the shaft of the femur. The ischium and pubis should come into the picture, as should also the lower half of the ilium. In some instances the limb may be abducted and rotated outwards to throw the head of the femur into prominence.

Fig. 187.—Normal hip-joint.

The Shaft of the Femur may be radiographed in two directions, antero-posterior and lateral. Only the lower two-thirds can be seen in the latter position. When the whole bone is required long, narrow plates may be used, the tube requiring to be centred at a greater distance, in order to get the whole of the bone. (These plates are made in several sizes, *e.g.* 15 × 6, 12 × 5 inches. They are extremely useful when a long bone requires to be radiographed.) The lateral view of the femur may be taken from either side.

The Knee-joint.—This important joint requires careful examination. (*a*) Both knee-joints may be taken on one plate. The tube is centred over the space between the two joints, and either an anterior or posterior view may be obtained. (*b*) Plate on posterior aspect of joint, tube in front. (*c*) Plate on anterior aspect, tube behind. The patella is well seen by this method of examination.

For the patella alone, the plate is placed on the front and the tube centred just outside the external border of the shaft, and directed obliquely downwards to avoid the shadow of the femur obscuring that of the patella. Plates taken in this position give good detail of the component parts of the joint. Fine detail should always be aimed at in these examinations. It is often possible to show apparently slight injury to the bone without an actual fracture. At a later date this may become the seat of chronic inflammatory changes, or tuberculosis of a joint may be a sequel to such an injury.

The points to observe are the general contour of the articular surface, and the space between the condyles, which is usually occupied by cartilage, but which frequently does not show any detail of the articular surface, though plates taken with a very soft tube show shadowy detail of the cartilages and the softer structures of the joint. The normal position of the patella, the articular surface of the upper end of the tibia, and the spine of the tibia should be noted. This is of great importance, for when cases are examined for injuries of the joint we must not overlook the relations of these parts to one another.

(*d*) The lateral view of the knee-joint is the most useful one from the point of view of diagnosis. In it we see the relations of the bony surfaces and a faint line of the articular cartilage, while in some instances the shadow of the internal articular cartilage is seen in a very faint, somewhat striated shadow. The outline of the patella is sharp and clearly cut, the pad of fat below the patella is frequently shown, and the ligamentum patellæ can be traced from the lower edge of the patella to its insertion into the tuberosity of the tibia. The two condyles of the lower end of the femur are clearly seen, and the head of the fibula with its articulation to the tibia is also shown. This view of the knee-joint may be taken from either side—internal or external.

The Tibia and the Fibula.—These bones may be radiographed from the front or the back, or laterally, from the inner or outer aspects of the limb.

The Ankle-joint.—There are four positions for the examination of this joint:

(*a*) Anterior, plate on the front of the limb.

(*b*) Posterior, plate on the posterior aspect of the limb, the foot at right angles to the leg.

(*c*) Lateral internal.

(*d*) Lateral external.

The Bones of the Foot: Tarsal, Metatarsal, and Phalanges.—For a general survey of the foot, the plate may be placed upon the inner aspect and the tube centred over the mid-point between the os calcis and the end of the toes.

By making another exposure the outer aspect of the foot may be brought into closer contact with the plate.

The os calcis can be examined in three positions :

(1) In the lateral position, plate on outer aspect of foot.

(2) Lateral aspect, plate on inner side of the foot.

(3) With a plate placed under the foot, the patient standing upon it, the tube being centred behind the bone, well above the insertion of the tendo Achillis, and directed obliquely downwards and forwards. A good view of the whole bone may be obtained in this way.

To obtain a reliable radiograph of the metatarsus and phalanges, the foot is placed upon the plate and the tube is directed downwards and slightly towards the heel. The patient may stand upon the plate ; or if he is lying on the back, the knee-joint is flexed, and the plantar aspect of the foot is placed in contact with the plate.

a

b

c

PLATE XX.—Normal Shoulder-joint.

a, Normal shoulder-joint, plate on posterior aspect of joint.
b, Normal shoulder-joint, plate on anterior aspect.
c, Normal shoulder-joint, arm abducted.

a

b

c

d

PLATE XXI.—NORMAL ELBOW AND FRACTURES IN REGION OF ELBOW-JOINT.

a, Normal elbow-joint, antero-posterior position.
b, Injury to epiphysis of olecranon.
c, Normal elbow-joint, lateral position.
d, Fracture through olecranon process.

THE DEVELOPMENT OF THE BONES

The importance of this section is great, as it is necessary to know the details of ossification and union of these bones. The following descriptions and drawings are based on those from well-known works on anatomy. The dates given are those which have long been recognised as the correct ones, but it is quite probable in the near future that many of those quoted may have to be revised as a result of systematic investigation on bone ossification by means of X-ray examinations. It is possible by this means to ascertain accurately the normal dates of union, but until the work of X-ray examination has been completely carried out it will be necessary to utilise the work of the anatomist.

The chief times of union need only be considered in those bones which are most likely to be injured. The ends of the long bones, the scapula, and the pelvis chiefly interest the radiographer. The usefulness of a complete though necessarily short description cannot be over-estimated. Diagrams and skiagrams will be used to illustrate changes, though it is obviously impossible to include examples of the epiphyses at all ages. It is hoped that this section will be found useful for reference, as it is hardly possible for the radiographer to carry all the dates in his mind.

The Clavicle.—Commencing with the bones of the upper extremity, we note that this bone is developed from three centres, two for the shaft and one for the sternal extremity. The centre for the shaft appears very early, *before any other bone*; according to Beclard, as early as the thirtieth day. The centre for the sternal end makes its appearance about the eighteenth or twentieth year, and unites with the rest of the bone about the twenty-fifth year.

The Scapula.—Development takes place by seven centres: one for the body, two for the coracoid process, two for the acromion, one for the posterior border, and one for the inferior angle. Ossification of the body of the scapula commences about the second month of fœtal life by the formation of an irregular plate of bone immediately behind the glenoid cavity. This plate extends itself so as to form the chief part of the bone, the spine growing up from its posterior surface about the third month. At birth the chief part of the scapula is osseous, the coracoid and acromion processes, the posterior border and inferior angle being cartilaginous. About the first year after birth ossification takes place in the middle of the coracoid process, which usually becomes joined with the rest of the bone at the time when the other centres make their appearance. Between the fifteenth and seventeenth years ossification of the remaining centres takes place in quick succession, and in the following order: first, near the base of the acromion and in the root of the coracoid process, the latter appearing in the form of a broad scale; secondly, in the inferior angle and contiguous part of the posterior border; thirdly, near the extremity of the acromion; and fourthly, in the posterior border. The acromion process, besides being formed of two separate nuclei, has its base formed by an extension into it of the centre of ossification which belongs to the spine, the extent of which varies in different cases. The two separate nuclei unite, and then join with the extension carried in from the spine. These various epiphyses become joined to the bone between the ages of twenty-two and twenty-five years. Sometimes failure of union between the acromion process and spine occurs, the junction being formed by fibrous tissue or by an imperfect articulation. In some cases of supposed fracture of the acromion with ligamentous union it is probable that the detached segment was never united to the rest of the bone.

The Humerus.—Development takes place by eight centres: one for the shaft, one for the head, one for each tuberosity, one for the radial head, one for the trochlear portion of the articular surface, and one for each of the condyles. The nucleus for the shaft appears near the centre of the bone in the eighth week, and soon extends towards the extremities. At birth the humerus is ossified nearly in its whole length, the extremities remaining cartilaginous. At the beginning of the second year ossification commences in the head of the bone, and during the third year the centre for the tuberosities makes its appearance usually by a single ossific point, but sometimes, according to Beclard, by one for each tuberosity, that for the lesser being small and not appearing until after the fourth year. By the fifth year the centres for the head and tuberosities have enlarged, and become joined so as to form a single large epiphysis.

The lower end of the humerus is developed in the following manner:—At the end of the second year ossification commences in the radial portion of the articular surface, and from this point extends inwards, so as to form the chief part of the articular end of the bone, the centre for the inner part of the articular surface not appearing until about the age of twelve. Ossification commences in the internal condyle about the fifth year, and in the external one not until about the thirteenth or fourteenth year. At about sixteen or seventeen years the outer condyle and both portions of the articulating surfaces (having already joined) unite with the shaft. At eighteen years the inner condyle becomes joined, whilst the upper epiphysis, although the first formed, is not united until about the twentieth year.

The Ulna.—Development takes place by three centres: one for the shaft, one for the inferior extremity, and one for the olecranon. Ossification commences near the middle of the shaft about the eighth week, and soon extends through the greater part of the bone. At birth the ends are cartilaginous. About the fourth year a separate osseous nucleus appears in the

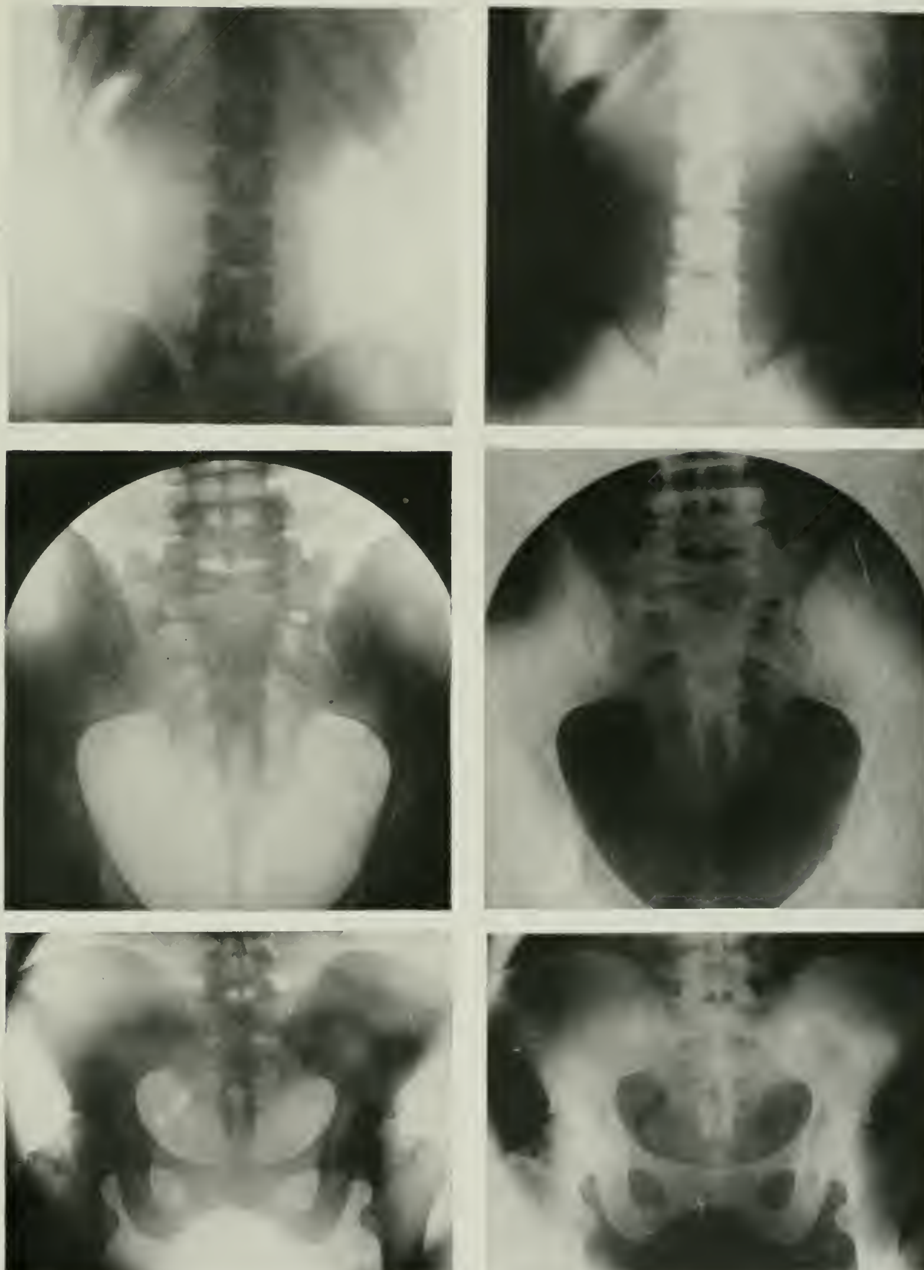


PLATE XXII.—Normal Lumbar Spine and Pelvis.

a, Normal lumbar spine.
b, Normal male pelvis.
c, Normal female pelvis.

a

b

c

PLATE XXIII.—NORMAL KNEE-JOINT.

a, Normal knee-joint, lateral view.
b, Knee-joint in young adult, irregularity in region of tubercle of tibia
c, Normal knee-joint, antero-posterior.

middle of the head, which soon extends into the styloid process. At about the tenth year ossific matter appears in the olecranon near its extremity, the chief part of this process being formed from an extension of the shaft into it. At about the sixteenth year the upper epiphysis becomes joined, and at about the twentieth year the lower one.

The Radius.—Development takes place by three centres, one for the shaft and one for each extremity. That for the shaft makes its appearance near the centre of the bone, soon after the development of the humerus commences. At birth the shaft is ossified, but the ends of the bone are cartilaginous. About the end of the second year ossification commences in the lower epiphysis, and about the fifth year in the upper one. At the age of seventeen or eighteen the upper epiphysis becomes joined to the shaft, the lower epiphysis becoming united about the twentieth year.

The Bones of the Hand.—The *carpal bones* are each developed by a single centre. At birth they are all cartilaginous. Ossification proceeds in the following order: in the os magnum and unciform an ossific point appears during the first year, the former preceding the latter; in the cuneiform, at the third year; in the trapezium and semilunar, at the fifth year, the former preceding the latter; in the scaphoid, at the sixth year; in the trapezoid, during the eighth year; and in the pisiform, about the twelfth year.

The *metacarpal bones* are each developed by two centres, one for the shaft and one for the digital extremity, for the four inner metacarpal bones; one for the shaft and one for the base, for the metacarpal bone of the thumb, which in this respect resembles the phalanges. Ossification commences in the shaft about the eighth or ninth week, and gradually proceeds to either end of the bone. About the third year the digital extremities of the four inner metacarpal bones and the base of the first metacarpal bones commence to ossify, and they unite about the eighteenth year.

The *phalanges* are each developed by two centres, one for the shaft and one for the base. Ossification commences in the shaft in all three rows at about the eighth week, and gradually involves the whole of the bone excepting the upper extremity. Ossification of the base commences between the third and fourth years, and a year later in those of the second and third rows. The two centres become united in each row between the eighteenth and twentieth years.

The Os Innominatum is a large, irregularly shaped bone, which, with that of the opposite side, forms the sides and anterior walls of the pelvic cavity. In young subjects it consists of the separate parts which meet and form the large cup-shaped cavity situated near the middle of the outer side of the bone; and although in the adult these have become united, it is usual to describe the bone as divisible into three portions: the ilium, the ischium, and the pubes. Development takes place by eight centres: three primary, one for the ilium, one for the ischium, and one for the pubes; and five secondary, one for the crest of the ilium, one for the anterior inferior spinous process (said to occur more frequently in the male than in the female), one for the tuberosity of the ischium, one for the symphysis pubis (more frequent in the female than in the male), and one for the Y-shaped piece at the bottom of the acetabulum.

These various centres appear in the following order : (*a*) in the ilium, immediately above the sciatic notch, at about the same period as the development of the vertebræ commences ; (*b*) in the body of the ischium, at about the third month of fœtal life ; and (*c*) in the body of the pubes, between the fourth and fifth months. At birth the three primary centres are quite separate, the crest, the bottom of the acetabulum, and the rami of the ischium and pubes being still cartilaginous. At about the seventh or eighth year the rami of the pubes and ischium are almost completely ossified. About the thirteenth or fourteenth year the three divisions of the bone have extended their growth into the bottom of the acetabulum, being separated from each other by the Y-shaped portion of cartilage, which now presents traces of ossification. The ilium and ischium then become joined, and lastly the pubes, through the intervention of the Y-shaped portion. At about the age of puberty ossification takes place in each of the remaining portions, and they become joined to the rest of the bone about the twenty-fifth year. It is important to bear in mind the development of the bones entering into the hip-joint, as this region has to be frequently examined for injuries and disease.

The Femur.—The femur is developed by five centres : one for the shaft, one for each extremity, and one for each trochanter. Of all the long bones except the clavicle it is the first to show ossification ; this commences in the shaft about the fifth week of fœtal life, the centres of ossification appearing in the epiphyses in the following order : first in the lower end of the bone at the ninth month of fœtal life—from this the condyles and tuberosities are formed ; in the head at the end of the first year of birth ; in the great trochanter during the fourth year ; and in the lesser trochanter between the thirteenth and fourteenth years. The order in which the epiphyses are joined to the shaft is the reverse of that of their appearance ; their junction does not commence until after puberty, the lesser trochanter being first joined, then the greater, then the head, and lastly the inferior extremity (the first in which ossification commenced), which is not united until the twentieth year.

The Patella.—Development takes place by a single centre, which makes its appearance about the third year. In two instances it has been seen cartilaginous throughout at a much later period (six years). More rarely the bone is developed by two centres placed side by side. Ossification is completed about the age of puberty.

The Tibia.—Development takes place by three centres, one for the shaft and one for each extremity. Ossification commences in the centre of the shaft about the seventh week, and gradually extends towards either extremity. The centre for the upper epiphysis appears at birth. It is flattened in form, and has a thin tongue-shaped process in front, which forms the tubercle. That for the lower epiphysis appears in the second year. The lower epiphysis joins the shaft at about the eighteenth, and the upper one about the twentieth year. Two additional centres occasionally exist: one for the tongue-shaped process of the upper epiphysis, the tubercle, and one for the inner malleolus.

The Fibula.—Development takes place by three centres, one for the shaft and one for each extremity. Ossification commences in the shaft about the eighth week of fœtal life, a little later than in the tibia, and extends gradually towards the extremities. At birth both ends are cartilaginous. Ossification commences in the lower end in the second year, and in the upper one about the fourth year. The lower epiphysis, the first in which ossification commences, becomes united to the shaft first, contrary to the rule which appears to prevail with regard to the junction of epiphysis with diaphysis. This takes place about the twentieth year. The upper epiphysis is joined about the twenty-fifth year.

The Bones of the Foot.—The *tarsal bones* are each developed by a single centre, excepting the os calcis, which has an epiphysis for its posterior extremity, just below the insertion of the tendo Achillis. It is seen as a small oval disc. The centres make their appearance in the following order: os calcis, at the sixth month of fœtal life; astragalus, about the seventh month; cuboid, at the ninth month; external cuneiform, during the first year; internal cuneiform, in the third year; middle cuneiform and scaphoid, in the fourth year. The epiphysis for the posterior extremity of the os calcis appears at the tenth year, and unites with the rest of the bone soon after puberty.

The *metatarsal bones* are each developed by two centres: one for the shaft and one for the digital extremity in the four outer metatarsals; one for the shaft and one for the base in the metatarsal bone of the great toe. Ossification commences in the centre of the shaft about the ninth week and extends towards either extremity, and in the digital epiphysis about the third year; they become joined between the eighteenth and twentieth years.

The *phalanges* are developed by two centres for each bone, one for the shaft and one for the metatarsal extremity.

The Hyoid Bone is a bony arch, shaped like a horse-shoe, and is of a quadrilateral form. Development takes place by six centres, two for the body and one for each cornua. Ossification commences in the body and greater cornua towards the end of fœtal life, the centres for the cornua first appearing. Ossification at the lesser cornua commences during the first or second year after birth.

The Sternum is a flat narrow bone, situated in the median line in the front of the chest, and consisting in the adult of three portions—the manubrium, the gladiolus, and the ensiform or xiphoid appendix. The sternum, including the ensiform appendix, is developed by six centres—one for the first piece or the manubrium, four for the second piece or gladiolus, and one for the ensiform appendix. Up to the middle of fœtal life the sternum is entirely cartilaginous, and when ossification takes place the ossific granules are deposited in the middle of the intervals, between the articular depressions for the costal cartilages, in the following order: in the first piece, between the fifth and sixth months; in the second and third, between the sixth and seventh months; in the fourth piece, at the ninth month; in the fifth, within the first year, or between the first and second years after birth; and in the ensiform appendix, between the second and the seventeenth and eighteenth years by a single centre, which makes its appearance at the upper part and proceeds gradually downwards. To these may be added the occasional existence, as described by Breschet, of two small episternal centres, which make their appearance, one on each side of the sterno-clavicular notch. These are regarded by him as the anterior rudiments of a rib, of which the posterior rudiment is the anterior lamina of the transverse process of the seventh cervical vertebra. It occasionally happens that some of the segments are formed from more than one centre, the number and position of which vary. Thus the first piece may have two, three, or even six centres. When two are present, they are generally situated one above the other, the upper one being the larger. The second piece has seldom more than one. The third, fourth, and fifth pieces are often formed from two centres, placed laterally, the irregular union of which will serve to explain the occasional occurrence of the sternal foramen or of the vertical fissure which occasionally intersects this part of the bone. Union of the various centres commences from below and proceeds upwards, taking place in the following order: the fifth piece is joined to the fourth soon after puberty; the fourth to the third between the twentieth and twenty-fifth years; the third to the second between the thirty-fifth and fortieth years; the second is occasionally joined to the first, especially at an advanced age.

Ossification of the Skull and the Vertebral Column.—It is unnecessary to deal extensively with the development of these bones. In *the vertebral column* each vertebra is ossified from three centres, two for the vertebral arch and one for the body. About the sixteenth year five secondary centres appear: one for the extremity of each transverse process, one for the extremity of the spinous process, one for the upper and one for the lower surface of the body. These fuse with the rest of the body about the age of twenty-five years.

These are the main points in the ossification of the vertebral column; but there are exceptions in the case of the first, second, and seventh cervical, and in the lumbar vertebræ.

The atlas is usually ossified from three centres.

The axis is ossified from five primary and two secondary centres.

The seventh cervical varies in its departures from the normal. A cervical rib is due to a persistence as a separate piece of the costal part, which becomes lengthened laterally and forwards.

The lumbar vertebræ have each two additional centres for the mammillary processes. The transverse process of the first lumbar is sometimes developed as a separate piece, which may remain permanently un-united with the rest of the body, thus forming a lumbar rib, a peculiarity rarely met with.

Radiographic Survey of the Joints showing Epiphyses

The Ankle-joint.—The lower epiphyses of the tibia and fibula are best seen in an antero-posterior view of the joint. The epiphyseal line is nearly horizontal in the case of both bones, but that of the fibula is at a lower level and comes opposite the ankle-joint. The internal malleolus forms the inner portion of the lower tibial epiphysis, while the external malleolus is practically

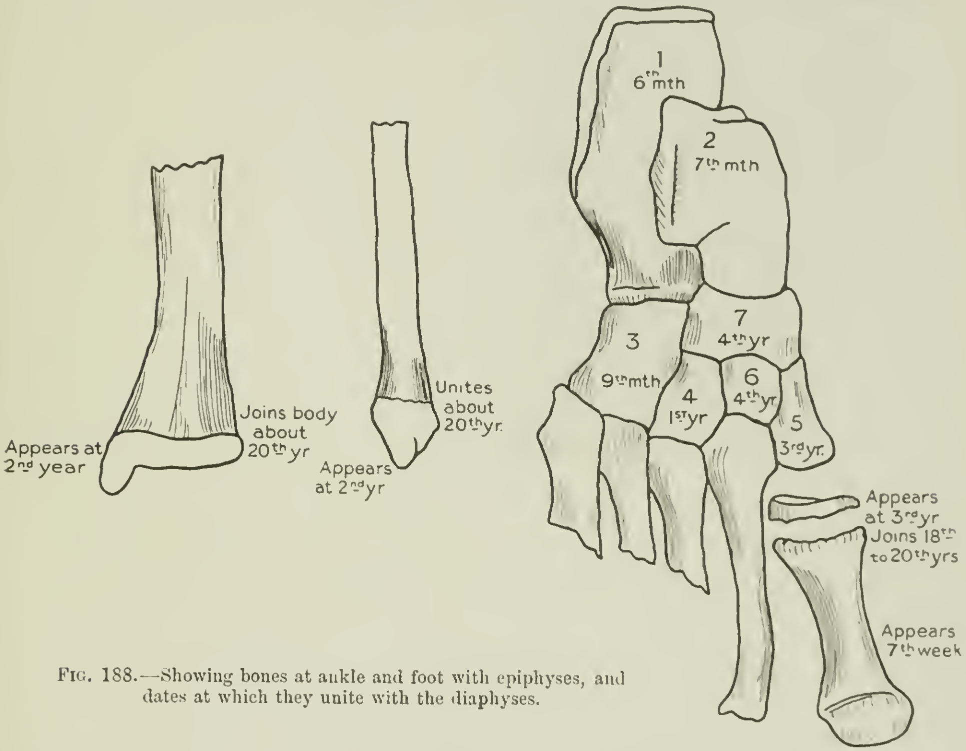


Fig. 188.—Showing bones at ankle and foot with epiphyses, and dates at which they unite with the diaphyses.

entirely composed of the lower epiphysis of the fibula. The latter epiphysis is greatly concerned in the increase in length of the fibula.

Table of Development of the Tarsus

The tarsal bones develop by a single centre. They appear approximately as follows:

Os calcis	Sixth month of fœtal life.

Sometimes this bone develops from two or three centres of ossification.

Astragalus	Seventh month of fœtal life.
Cuboid	Ninth month of fœtal life.
External cuneiform . . .	First year.
Internal cuneiform . . .	Third year.
Middle cuneiform . . .	Fourth year.
Scaphoid	Fourth year.

The ossific centre for the epiphysis of the os calcis appears at the ninth year, and may sometimes unite before puberty. It may develop from two centres.

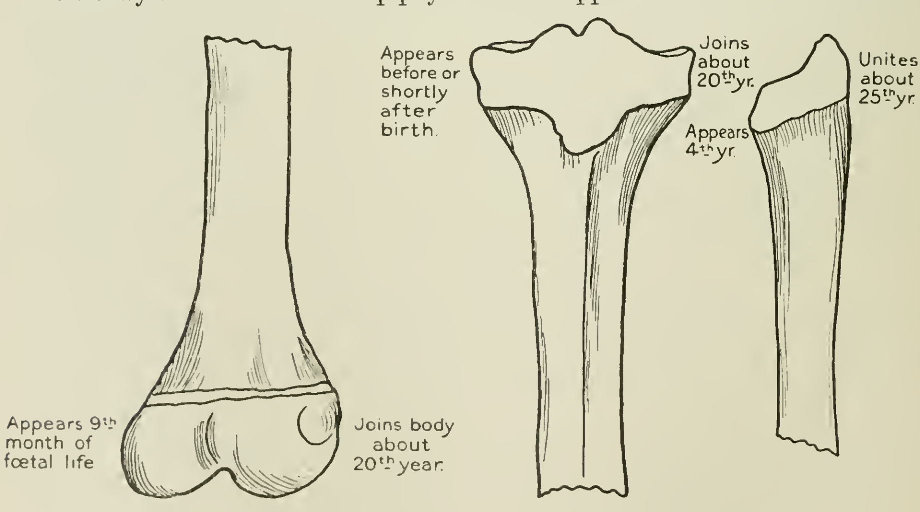
Knee-joint.—The epiphyses entering into the formation of this joint are of the greatest importance, for it is one of the joints most frequently injured. The epiphysis of the lower end of the femur is the only one in which bone is formed before birth.

Fig. 189.—Foot.
Antero-posterior view, plantar aspect of foot on plate. Age 14.

In an antero-posterior view it is seen as a large irregular bony mass, forming the entire lower end of the femur. The epiphyseal line is seen at the level of the adductor tubercle on the inner side. It is wavy in outline, rises sharply towards the centre, and has a slightly lower level at the outer side of the bone.

The epiphyses of the tibia and fibula will be seen in Figs. 191 and 192. The epiphyseal line of the tibia resembles that of the line of the lower end of the femur. The upper epiphysis of the fibula is a small mass, appearing to rest on the top of the shaft.

In a lateral view the epiphyseal lines of the femur and fibula are nearly horizontal. The epiphysis of the upper end of the tibia is seen



Lower end of femur. Upper end of tibia. Upper end of fibula.

Fig. 190.—Diagram to show the epiphyses entering into the knee-joint.

to have a tongue-like projection extending down the front of the bone to

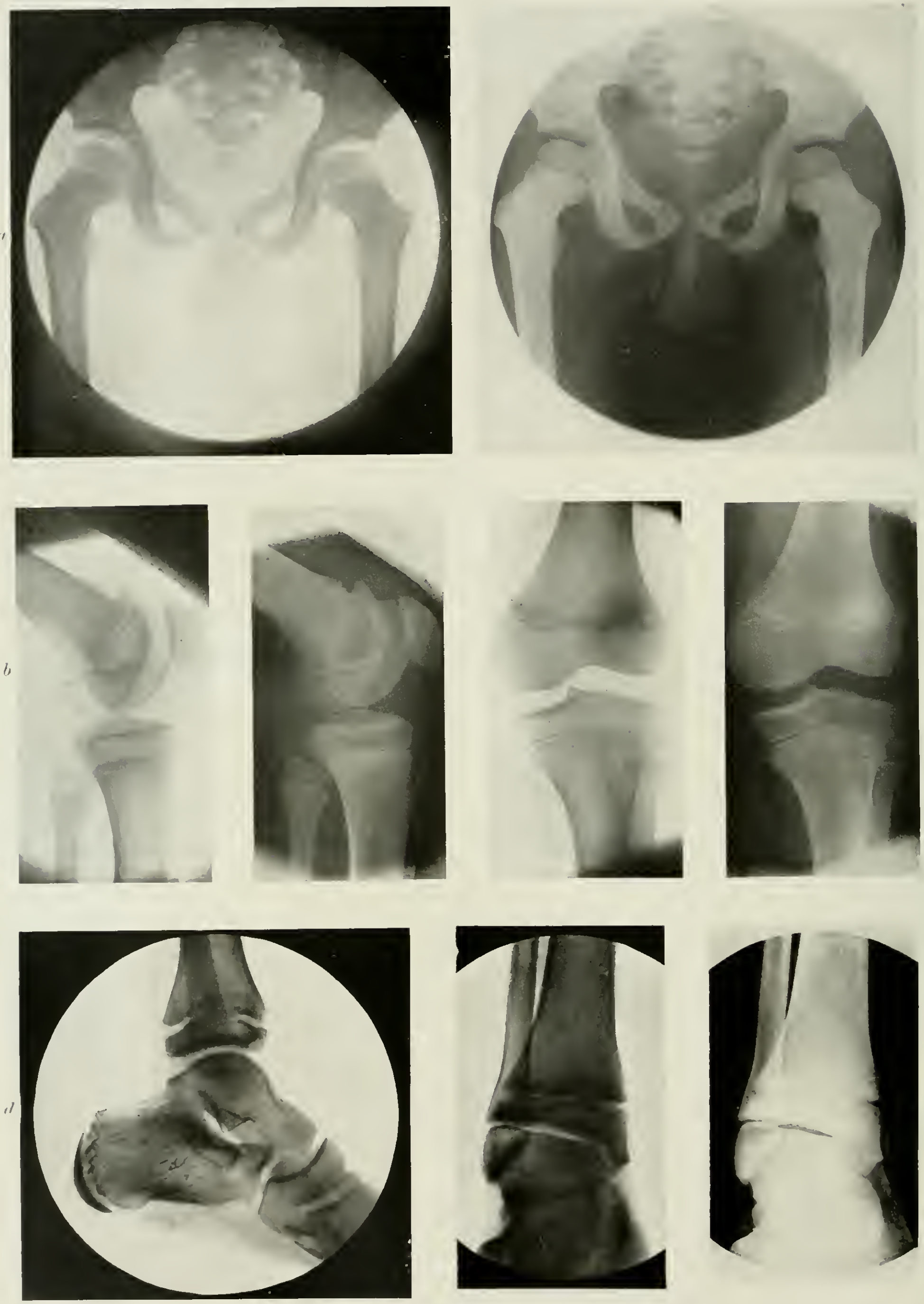
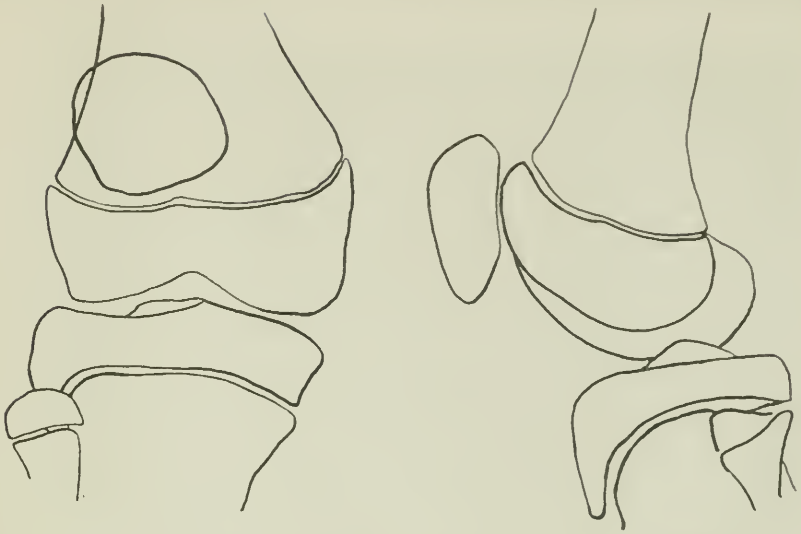


PLATE XXIV.—Showing Epiphyses of Hip, Knee, and Ankle Joints.

a, Pelvis and hip-joints in a child of 5-6 years.
Knee-joint in a child 10-12 years. *b*, Lateral view. *c*, Antero-posterior view.
Ankle-joint in a child 10-12 years. *d*, Lateral aspect. *e*, Antero-posterior aspect.

the tubercle of the tibia. In some instances this projection does not reach



Antero-posterior. Lateral.

FIG. 191.—Diagrams to illustrate the appearances of the epiphyses at the knee-joint, traced from radiographs.

so far as the tubercle, and the latter is seen arising from a separate centre of ossification. It is frequently the seat of injury and inflammation (see Plates XXIII. Fig. *b*, and XXXIII. Fig. *a*).

The Hip-joint.—The epiphysis of the upper end of the femur includes merely the articular head of the bone and forms no part of the neck. In an X-ray picture it resembles somewhat the appearance of the epiphysis of the upper end of the humerus. The greater and lesser trochanters arise from separate centres of ossification, but these are

FIG. 192.—Lateral view of knee-joint, showing epiphyses. Note prolongation of tibial epiphysis on anterior aspect of tibia. Age, 14 years.

less frequently seen in radiographs than is the larger epiphysis (see Plate XXIV. *a*).

Fig. 193.—Antero-posterior view of knee-joint showing epiphyses. Plate on posterior aspect of joint.

Fig. 194.—Fracture of tibia and fibula. Practically no displacement. The appearances of the epiphyses at both ends of the bones indicate the age of the patient to be about 3 years. The fibula has a convexity towards the tibia.

The Wrist-joint.—The epiphysis of the lower end of the radius is seen in an antero-posterior view of the joint as a wedge-shaped shadow, and is thicker on the outer than on the inner side of the wrist. The epiphyseal line, though irregular and wavy, is never rough and jagged as in a fracture. This epiphysis has a great share in the increase in length of the shaft.

The epiphysis of the lower end of the ulna is seen at a higher level than that of the radius and shows the prominence of the styloid process on its inner side.

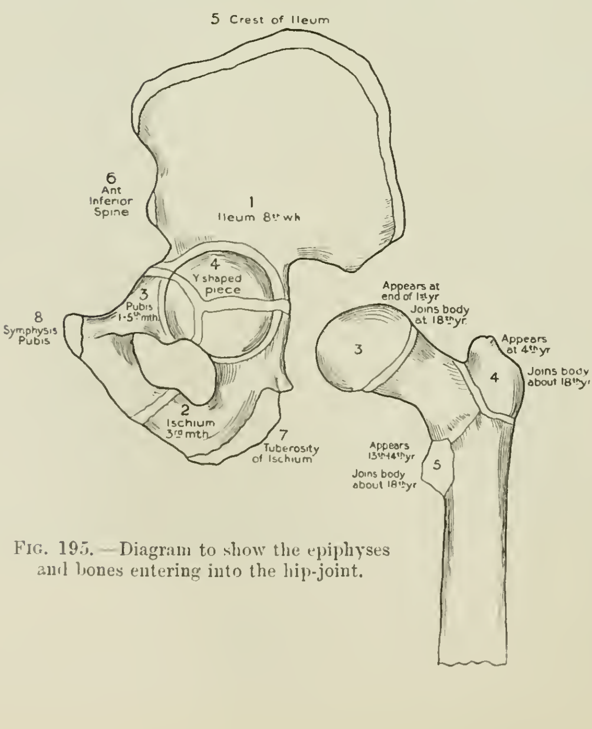


Fig. 195.—Diagram to show the epiphyses and bones entering into the hip-joint.

The centres of ossification for the carpal bones show according to the age at which the joint is examined (see "Ossification").

FIG. 196.—Pelvis and femora of a child two days old, showing ossification of bones of pelvis, hip and knee joints. Note lower epiphyses of femur present at birth.

TABLE OF OSSIFICATION FOR CARPAL BONES

The carpus is entirely cartilaginous at birth. Centres appear for these carpal bones at the following times:

Os magnum . .	first year.	Trapezium . .	fifth year.
Unciform . .	second year.	Scaphoid . .	seventh year.
Cuneiform . .	third year.	Trapezoid . .	eighth year.
Semilunar . .	fifth year.	Pisiform . .	twelfth year.

The "os central," lying between the bones of the first and second rows, is present in man as a small cartilage situated between the "trapezoid," trapezium, os magnum, and "scaphoid," at the second month, and disappears about the fourth month of fœtal life. In rare cases it persists as a separate bone in the adult.

The epiphyses of the four inner metacarpal bones are seen at the distal ends of the shafts, but in the phalanges and in the metacarpal bone of the thumb the epiphyses are found at the proximal ends of the respective bones.

The Elbow-joint.—The lower epiphysis of the humerus at the age of five or six years merely shows the centre for the capitulum as a small round mass. In an antero-posterior picture of the joint it is seen as a wedge-shaped mass, its lower surface being convex, and lying below the external condyle. At twelve the centres for the trochlea and the external epicondyle have appeared, and have united with the centre for the capitulum, forming the lower epiphysis. The lower end of the humerus is one of the bones most frequently involved in injuries and disease, but the other bones entering

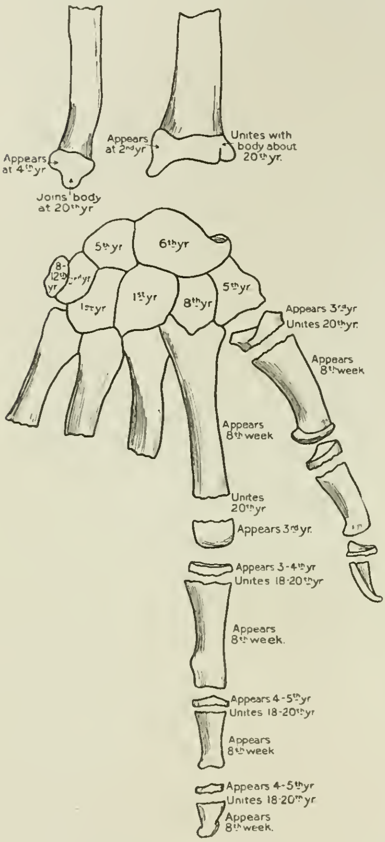


FIG. 197.—Diagram showing ossification of the bones of the hand and the wrist-joint with the times of union of epiphyses with diaphyses.

FIG. 198.—Hand of a child over five years of age. Shows development of bones of lower ends of radius and ulna, carpal bones, metacarpals, and phalanges. The epiphysis for lower end of radius well developed. The ulnar epiphysis has not yet appeared. The os magnum and unciform, semi-lunar and cuneiform bones are also shown. The pisiform is not shown. Note also the centre for the proximal end of the metacarpal bone of the thumb.

into the joint should also be remembered in relation to the times at which their epiphyses join the diaphyses. The internal epicondyle is not a part of the lower epiphysis of the humerus, but is formed from a separate centre of ossification. In an X-ray picture it is seen as a small, oval mass, higher up on the inner side of the humerus, and intimately connected with the internal condyle. The epiphysis of the head of the radius is seen as a small disc, just above the upper end of the bone. In a lateral view of the joint at about five years the lower epiphysis of the humerus appears to be semi-lunar in shape, fitting closely to the lower end of the shaft. At a later age the parts become accentuated, and great care must be exercised in distin-

FIG. 199.—Hand of a child, $5\frac{9}{12}$ years. Showing stage of ossification.

FIG. 200.—Shows stage of ossification in a young adult under twenty years.

guishing the normal appearances when examining the joint for suspected injuries. A normal radiograph should always be compared with the suspected one if mistakes are to be avoided.

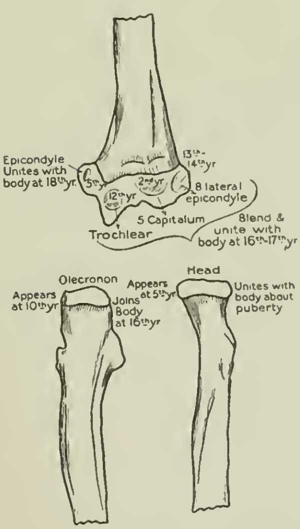


FIG. 201.—Diagram showing epiphyses of the bones forming the elbow-joint.

FIG. 202.—Elbow-joint, antero-posterior view, showing epiphyses. Age 14.

The Shoulder-joint.—The upper epiphysis of the humerus is found as a dome-shaped mass, which appears to rest on the top of the shaft. It is composed of the centres for the head and for the greater and lesser tuberosities, which unite to form the epiphysis. The epiphyseal line lies a little way above the surgical neck, and is not horizontal, but is higher in the middle of the shaft than at the outer and inner sides. The increase in length of the humerus takes place principally at this epiphysis, and hence its great importance.

FIG. 203.—Lateral view of elbow-joint, to show epiphyses. Age 14.

Certain anatomical facts are worthy of note when we are considering inflammatory conditions and injuries of the bones in the neighbourhood of joints, more especially in children and young adults. It is important to keep in mind the chief centres of ossification and the periods at which the epiphyses join the diaphyses in the joints most liable to injury; but as it is obvious that one cannot readily recall the whole of them it is hoped that a reference to the foregoing pages will be helpful. The marked differences between the appearances of joints in early youth and in adult life must be noted to avoid errors in diagnosis. Fractures are relatively more frequent in adults, while greenstick fracture and separation of epiphyses are more prevalent in injuries occurring before the epiphyses have joined up with the diaphyses.

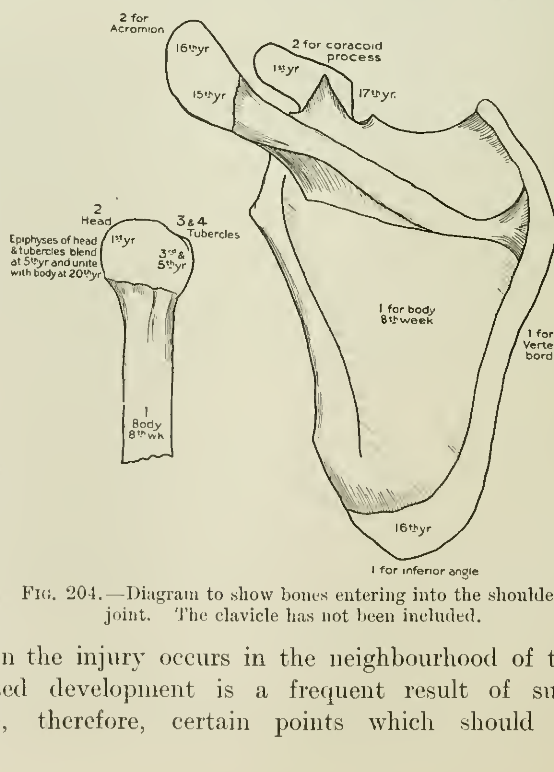


FIG. 204.—Diagram to show bones entering into the shoulder-joint. The clavicle has not been included.

The after history of an injury is greatly influenced in its results when the injury occurs in the neighbourhood of the epiphyseal line. Arrested development is a frequent result of such an injury. There are, therefore, certain points which should be remembered in relation to the principal joints of the body which will be briefly mentioned, reference to figures illustrating these points being made as occasion arises.

Fig. 205.—Normal shoulder (12 years of age) showing epiphyses at head of humerus.

Sesamoid Bones.—These are small rounded masses, cartilaginous in early life, osseous in the adult, which are developed in tendons which exert a great amount of pressure upon those parts over which they glide. It is said that they are more commonly found in the male than in the female, and in persons of an active muscular habit than in those who are weak and debilitated. They have a free articular facet.

The sesamoid bones *of the joints* in the lower extremity are: the patella,

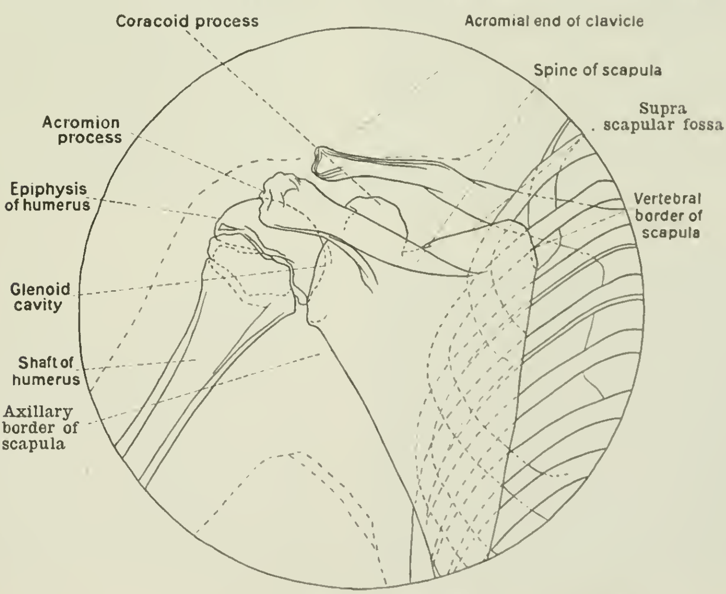


Fig. 206.—Diagram to illustrate the anatomical points in Fig. 205.

in the tendon of the quadriceps extensor; two small sesamoid bones in the tendon of the flexor brevis pollicis, opposite the metatarso-phalangeal joint of the great toe ; and occasionally one at the metatarso-phalangeal joint of the second toe, of the little toe, and, still more rarely, of the third and fourth toes.

In the upper extremity they are found on the palmar aspect of the metacarpo-phalangeal joint in the thumb, developed in the tendon of the flexor brevis pollicis, occasionally one or two opposite the metacarpo-phalangeal articulations of the fore and little fingers, and still more rarely one opposite the corresponding joints of the third and fourth fingers.

Those found *in the tendons*, which glide over certain bones, occupy the following positions : one in the tendon of the peroneus longus, where it glides through the groove in the cuboid bone ; one which appears later in the tendon of the tibialis anticus, opposite the smooth facet on the internal cuneiform bone ; one is found in the tendon of the tibialis posticus, opposite the inner side of the astragalus ; one in the outer head of the gastrocnemius behind the outer condyle of the femur, and one in the psoas and iliacus, where they glide over the pubes.

Sesamoid bones are found occasionally in the *tendon of the biceps*, opposite the tuberosity of the radius ; in the tendon of the glutæus maximus, as it passes over the great trochanter, and in the tendons which wind round the inner and outer malleoli.

a

b

c

d

PLATE XXV.—FRACTURES IN REGION OF THE SHOULDER-JOINT.

a, Fracture through great tuberosity.
b, Exostosis of inferior angle of scapula.
c, Fracture of body of scapula ; gunshot injury.
d, Fracture at upper end of shaft of humerus, there is no displacement. Note the epiphyseal line of head of humerus.

INJURIES OF BONES AND JOINTS

The methods which are employed for the determination of injuries of bones and joints are (1) fluoroscopy, (2) radiography. Both should be employed, the former for the determination of the presence of an injury and for the purpose of centering the tube under the injured part. In regard to diagnosis by screening only, a few words of caution are necessary. While in a number of gross lesions with a degree of displacement and dislocations it is possible to make a positive diagnosis at once, it must be pointed out that a *negative diagnosis* of injury to bone should never be made on the screen examination alone. A plate should always be exposed after the screen examination has been made if the operator has not been able to detect an injury. If this procedure is followed it is possible to avoid making many serious errors in diagnosis. Fractures of the phalanges, when there is no dis-

Fig. 207.—Radiogram of finger: antero-posterior view. The fracture is not visible in this position.

Fig. 208.—The same finger: lateral view. Showing fracture of posterior aspect at base of terminal phalanx of index finger.

placement, are frequently unrecognisable under the screen. Figs. 207 to 209 illustrate the difficulties of diagnosis if the screen is used with the limb in one position only. Either of these injuries might have escaped detection under those circumstances.

Figs. 207 and 208 show a fracture of the bone of the terminal phalanx of the index finger. In the antero-posterior view there is no sign of fracture, but in the lateral view the fracture shows distinctly.

Fig. 209 shows a fracture of the fibula; in *a* (antero-posterior view) no injury can be detected. By everting the foot position *b* was obtained, and a well-marked fracture of the lower end of the fibula appears. These two cases well illustrate the importance of carefully examining all cases of injury in at least two positions. Crushing of the bones in the neighbourhood of a joint, sprain, fractures, and many so-called trivial injuries to bones and joints will be overlooked if the radiographic method is not employed.

The examination of the bones and joints in the normal individual is comparatively easy, in the injured patient it is often a matter of extreme

a

b

Fig. 209.—Fracture of the fibula. (From the Seamen's Hospital, Greenwich.)
a. Antero-posterior view, in which no injury can be detected. *b*. Position obtained by everting the foot, when a well-marked fracture of the lower end of the fibula was revealed.

difficulty to adjust the tube and plate. Great ingenuity may have to be displayed in certain cases. The best method to employ is to place the patient upon a radiographic couch. It is convenient to have a good supply of cushions, air-bags, and sand-bags in order to get a position of comparative ease for the patient. Many patients complain of the hardness of the X-ray couch.

The tube should be accurately centred in the tube-box, and its focus point should be capable of ready adjustment by movements in two directions under the couch. With a plumb line it is possible quickly to centre the tube under the central point of a joint or bone.

Injuries of the Skull and Spine

The skull is frequently examined for evidence of fracture. Fractures may occur at the base, when they can be recognised by departures from the normal on a lateral or antero-posterior radiograph. Both positions should be taken. In children, when the sutures are very evident, care must be exercised to distinguish between these and a fracture. In the region of the temporal bone this is most important.

Fracture of the Vault of the Skull.—A depressed fracture can be readily detected when a lateral view of the skull is taken. The extent of the injury and the degree of depression should be noted.

FIG. 210.—Comminuted fracture of angle of lower jaw.

This skiagram shows the teeth, particularly the roots in the lower jaw. The inferior dental canal is seen running along the jaw. One tooth shows extensive caries.

Fracture at the base of the skull is difficult to determine. It may occur at any part of the base and may be represented as a fine fissure in the bone. When this occurs in the neighbourhood of the sutures it is often impossible to make a positive statement as to the nature of an injury. In children where the sutures have not closed it is still more difficult. In doubtful cases stereoscopic radiographs should be taken. Clinical signs should always be taken into account.

FIG. 211.—Fracture through ramus of lower jaw. The soft parts show well.

Fractures of the Orbital Region are very difficult to distinguish. Fine detail must be obtained, and care should be exercised to obtain radiographs which show no evidence of movement on the part of the patient. This is often a matter of difficulty, because patients suffering from injury to the skull and brain are not likely to keep the head steady long enough to allow of a sufficient exposure ; hence in these cases very rapid exposures are indicated, and intensifying screens should be used to cut down the exposure to the minimum. The orbital margins should be carefully examined to detect slight departures from the normal, which may be the only evidence of fracture. Stereoscopic plates will be found most useful in this region.

The Zygomatic Arch is occasionally broken. There may be a depression of the bone, this being readily detected when an antero-posterior radiograph is obtained.

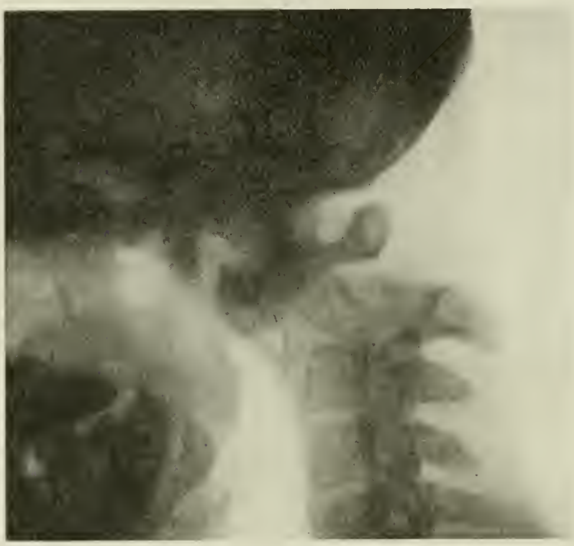


Fig. 212.—Fracture dislocation of cervical vertebræ.

Fracture of the Superior Maxilla.—The upper jaw is frequently involved in face injuries, gunshot wounds, and occasionally by injuries to the teeth when the antrum of Highmore may be opened. The exact extent of the injury is often very difficult to determine. The palatine arch may be disturbed. Careful examination of the radiograph is necessary when injuries in this region are suspected.

Fracture of the Inferior Maxilla (Mandible). — This bone is frequently injured. Four positions are available : (1) antero-posterior ; (2) lateral ; (3) film in the mouth ; (4) oblique lateral. The condyle may be injured when the bone is subjected to direct violence. The coronoid process may be fractured by either direct or indirect violence.

It is somewhat difficult to get a good radiograph of one side of the lower jaw, because of the superimposing of the shadows. Probably the best method to employ is to centre the tube behind and a little below the angle of the jaw. With the plate on the injured side, the tube is centred over a spot behind and below the angle of the uninjured jaw, thus avoiding the overlapping of the latter.

By using the above method it is possible to obtain a picture of the side required, showing the whole of the lower jaw in profile, the temporo-maxillary articulation being well shown. This is also a useful method when it is necessary to examine the jaw for tumour or dental disease.

Fractures of the Nasal Bones.—These are occasionally fractured on one or both sides. A plate on the injured side is generally sufficient to show the injury. An antero-posterior view is also useful. Stereoscopic pictures may be necessary. A small piece of X-ray film placed in contact with the side of the nose will give a sharp picture.

Fig. 213.—Fracture of base of odontoid process. Radiogram obtained by use of extension tube centred over the mouth.

Injuries of the Cervical Vertebræ.—Two positions have already been described. The lateral is the most useful, for it shows readily very slight departures from the normal.

Fracture dislocation of the cervical vertebræ is a not uncommon injury. Any part of the cervical region may be the seat of a dislocation. The appearances are unmistakable when well marked, but the doubtful cases give rise to considerable difficulty in diagnosis. Fig. 212 illustrates a partial fracture dislocation of the upper cervical vertebræ, which was not definitely diagnosed for several weeks after the injury occurred.

Fig. 214.—Fractures of vertebral border of scapula and three ribs (gunshot wound).

Injuries of the Dorsal Vertebræ.—The dorsal spine may be involved in injuries of the thorax. Ribs may be fractured and the vertebral column crushed, or partial dislocation may be present. Two positions are useful: (1) a postero-anterior, that is, the plate on the back and the tube in front; (2) a lateral, to show the bodies of the vertebræ. It is often extremely difficult to show fractures of the posterior parts of the spinal column. Crushing and displacement of the bodies may be clearly indicated. Fracture of the transverse process sometimes occurs. When there is considerable displacement it is possible to demonstrate the position of the lesion.

Injuries of the lumbar vertebræ.—The lower lumbar vertebræ are very difficult to get clear pictures of; care must be exercised in centering the tube in order that no distortion of the fifth transverse process may occur. If this is thrown closer to the ilium it may well simulate a displacement or injury.

Fracture of the Ribs

The demonstration of fracture of the ribs is often a matter of great difficulty. This is particularly so when the bone is broken through and no displacement takes place. Fracture of the anterior portion, *i.e.* the sternal end, of the rib near to and involving the costal cartilage is often very difficult to show satisfactorily. Fracture of the lateral portion of the rib is also a difficult one to determine. It may give only evidence of a minute crack. The best positions for showing fractures of these bones are antero-posterior and lateral. The latter is often a difficult position in which to show a fracture, especially in stout patients.

Fracture of the Clavicle

(1) At the acromial end external to the trapezoid ligament, usually produced by direct violence. The inner fragment retains its position unaltered, but the outer fragment is dragged down by the weight of the arm, and forwards by the action of the muscles, so that it may lie at nearly right angles to the rest of the bones.

(2) Between the coraco-clavicular ligaments. There is little displacement. It may be shown radiographically as a fissured fracture of the bone.

(3) Through the greater convexity of the bone. There is frequently considerable displacement. (See Plate XI. Fig. *d.*)

(4) At the sternal end. This may be complicated by a partial displacement.

(5) Greenstick fracture of the clavicle, a common injury in children. Frequently only a decided bend on the bone is seen, but occasionally a minute crack may be detected.

Fracture of the Scapula

The Body of the scapula may be broken in cases of injury due to direct violence, the fracture being usually of the fissured or stellate variety when the flat surface of the bone is damaged. The vertebral border is occasionally involved in these injuries. The scapula is frequently injured in gunshot wounds; an injury to the bone may be the only indication that a bullet has passed through the joint.

The Spine of the scapula may also be fractured, generally as the result of direct violence.

The Acromion Process may be broken by direct violence applied to the point of the shoulder. The arm hangs powerless by the side, and the shoulder is flattened. The irregularity of the bone can be readily detected, and crepitus can be elicited by raising the elbow and rotating the arm. Occasionally merely the tip is detached, and then the above signs will not be present.

FIG. 215.—Sub-coracoid dislocation of the head of the humerus.

The Coracoid Process is rarely fractured, and only from direct violence. There is but little displacement, on account of the many powerful ligaments attached to it. In spite of the attachment of such powerful muscles as the pectoralis minor, biceps, and coraco-brachialis, the displacement is not great, as the process is kept in position by the coraco-clavicular ligament.

The Neck of the scapula may be fractured immediately behind the glenoid cavity, but this is a rare injury. Its existence has been doubted. Astley Cooper and South have stated that cases so described are in reality fractures of the upper end of the humerus. There is, according to South, no specimen in any of the London museums illustrating fracture of the neck of the scapula (Erichsen). Walsham describes one case of this variety of fracture which is in Guy's Hospital museum, and Rose and Carless figure an instance of this variety. It is usually due to direct violence ; a portion of the articular surface is broken off and displaced downwards. Plate XI. Fig. *c* illustrates a case of this rare variety of fracture through the lower segment of the glenoid cavity, with displacement downwards of the fragment. The patient was admitted to the Great Northern Central Hospital suffering from an injury to the shoulder, which was taken to be a dislocation of the head downwards. The skiagram shows the fracture and the typical displacement.

A case recorded by Spence is the first authentic instance of this fracture. A patient who had fallen upon the shoulder whilst in a state of intoxication was brought into the Edinburgh Royal Infirmary. The man died some days afterwards from meningitis. "The fracture was found to pass obliquely from below upwards and forwards, commencing about half an inch behind the origin of the long head of the triceps, and separating the neck and four-fifths of the lower part of the glenoid cavity from the scapula. The long head of the triceps and the whole of the glenoid ligament had also been torn from the upper fragment of the glenoid cavity, and carried along with the displaced portion." In fractures through the neck of the scapula the coracoid process would necessarily follow the glenoid cavity, being detached along with it. Mobility of the coracoid would, therefore, be a valuable sign of this rare fracture.

Fractures of the Humerus

The fractures to which this bone is liable may be conveniently divided into three groups :

(1) Those affecting the upper extremity, or that part which is situated above the surgical neck.

(2) Those of the shaft, and

(3) Those of the lower articular extremity.

Fractures at the Upper End at the Humerus.—(*a*) Of the *anatomical neck*, the so-called intracapsular fracture. This is always due to blows upon the shoulder, never to direct violence. It is evidenced by signs of a severe local trauma, with loss of mobility of the arm. The head of the humerus is found to be irregular in shape on examination from the axilla, and the fragment, if detached, may be felt. Crepitus is obtained on moving the arm, and there is slight shortening.

(*b*) Fracture through the *surgical neck*. This is a common injury. There may or may not be a considerable degree of displacement, or the lower point of the bone may be impacted into the upper ; the latter may be partially split.

(*c*) The *great tuberosity* of the humerus is frequently detached and displaced.

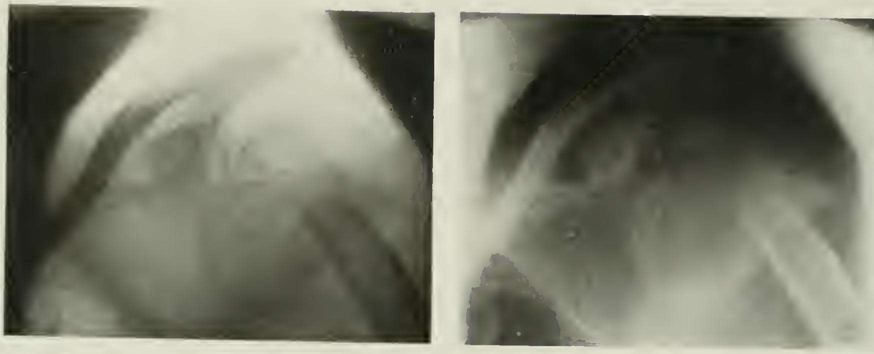
(*d*) The *epiphysis* of the head may be detached from the shaft, and there may be a considerable degree of displacement.

Fracture of the Shaft of the Humerus.—This bone is frequently fractured, and the injury may occur at any part of its length. The most common injury is about the junction of the upper with the middle third. The displacement may be considerable. An unusual displacement is shown in Fig. 218, a transverse fracture with marked rotation of the elbow-joint inwards ; the lower fragment of the humerus is nearly at right angles to the upper. The head of the radius appears to have been injured.

Injuries in the Region of the Elbow-joint

Fracture of the Lower End of the Humerus.—The humerus is frequently involved in injuries of the elbow-joint in adults and in children. It gives rise to a typical displacement, which is clearly revealed upon examination of the radiographs obtained. The displacement varies with the direction of the injury. The lower end, along with the elbow-joint, may be displaced backwards, while there may also be some lateral displacement and rotation. Stereoscopic radiographs are extremely useful in these cases.

a



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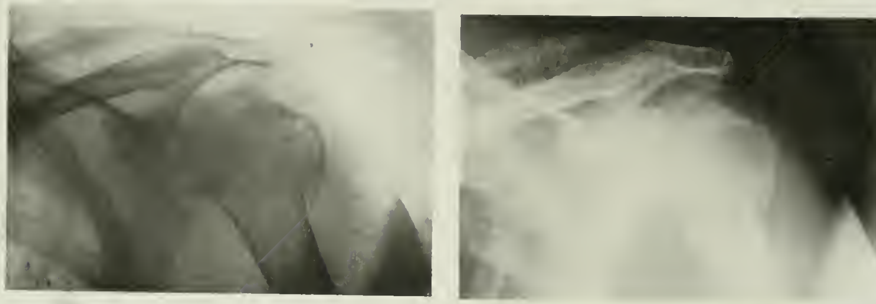

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PLATE XXVI.—FRACTURES IN REGION OF THE SHOULDER-JOINT.

a, Fracture at upper end of humerus, a longitudinal splitting of the shaft with head displaced forwards and downwards (dislocation of the head).

b, Separation of the great tuberosity of the humerus.

c, Fracture through lower aspect of glenoid cavity.

d, Fracture of the clavicle (middle third), the base of the acromion process is irregular and appears to be fractured.

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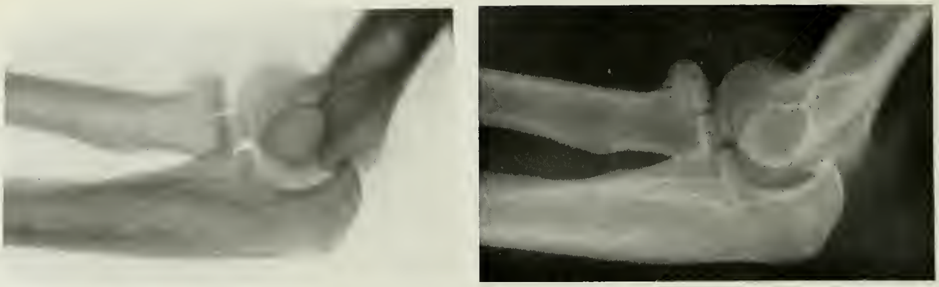

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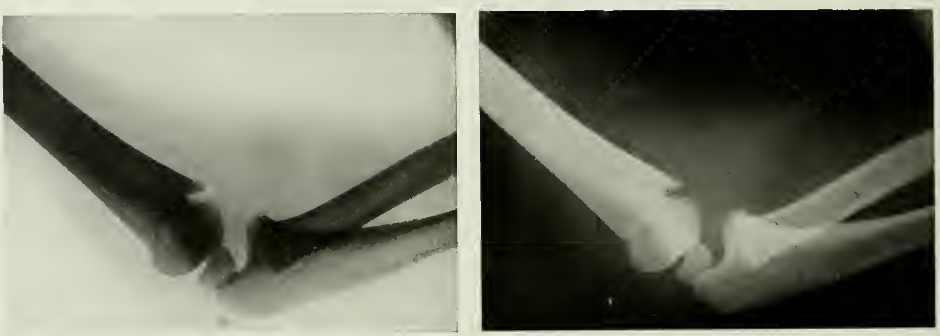

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PLATE XXVII.—FRACTURES IN REGION OF ELBOW-JOINT.

a, Vertical fracture of head of radius.
b, Fracture through head of radius, displacement forwards of fragment.
c. Fracture through lower end of humerus above epiphyseal line, displacement backwards.
d, Fracture dislocation at elbow-joint.

FIG. 216.—Fracture of shaft of humerus and upper end of radius (shrapnel wound).

FIG. 217.—Fracture of lower end of humerus, with backward displacement of the lower fragment.

FIG. 217*a*. —Gunshot injury to elbow-joint showing destruction of joint and excess of callus formation.

FIG. 218.—Fracture of shaft of humerus; rotation of lower fragment and elbow-joint.

FIG. 219.—Fracture through external condyle with forward and upward displacement of the fragment of bone. The presence of chronic arthritic changes in the joint indicates that the injury is one of some standing. The radiograph was taken many months after the primary injury.

Separation of the Epiphysis of the lower end of the humerus is a

Fig. 220.—Dislocation of elbow-joint.

common injury in this region. It is very difficult to show in children, and requires more careful examination than any other injury.

Dislocations of the Elbow-joint are common, and frequently combined with fracture in the region.

Fig. 221.—Fractures through shafts of radius and ulna. The position of both bones is faulty. There is also a fracture through the lower end of the radius.

Fracture of the Olecranon may be complete or incomplete. It is commonly a transverse fracture, though it may be oblique or vertical, or the upper portion may be shattered. The displacement varies with the extent of the fracture.

Fracture of the Coronoid is a rare injury. It is generally associated with a dislocation of the forearm backwards. When the fracture is reduced, the bones tend to slip out again readily.

Fracture of the Head of the Radius is by no means an uncommon injury ; it may be complete or incomplete.

Fracture of the Shaft of the Radius and Ulna

One or other of the bones may be broken. The usual seat of injury is near the middle of the shaft, in which case both bones are frequently broken, and the displacement may be considerable. One or other bone may be involved in injuries at the elbow-joint or wrist-joint.

Injuries at the Wrist-joint

Fracture of the lower end of the radius and ulna is included in the description of the common Colles fracture. The results of the analysis of a large number of cases of fracture at the wrist-joint investigated by Dr. R. W. A. Salmond and the author may be quoted (*Lancet*, Nov. 2, 1912).

Antero-posterior. Lateral.

Fig. 222.—Fracture of shaft of ulna (the result of a gunshot wound).

(*a*) *The Radius.*—This shows injury in 93 per cent of the total number of cases. The large percentage is without doubt due to the important part the lower end of this bone takes in the mechanism of the wrist-joint. Most injuries at the wrist are carried up from the hand and are transmitted through the radius, hence the great frequency of damage to the lower end of the bone. The radius alone is injured in 41 per cent of the total number of cases, showing that, while it is injured in nearly every case, the injury is more often distributed to some of the other bones than confined to itself.

The radius is injured along with the styloid process of the ulna in 42 per cent of the total number of cases.

The radius is damaged, together with the shaft and the styloid of the ulna, in 3 per cent of cases. This is therefore infrequent, and the more so as the majority of the instances are due to a fracture carried up from the damaged styloid process into the shaft of the ulna. The frequency of injuries to the radius and the shaft of the ulna is also low—namely, 3 per cent. It will be noticed how much more frequently the radius is injured with the styloid of the ulna than with the shaft, and it is interesting to compare this with the corresponding injury in the un-united epiphyses series. Injury is confined to the radius and carpus in 4 per cent of cases.

Direction of Injury.—The great majority are transverse, 67 per cent; T-shaped in 16 per cent; fracture from the centre of the lower end across the styloid process, 8 per cent; V-shaped, 4 per cent; fracture of styloid process, 3 per cent; oblique, 2 per cent; longitudinal, 2 per cent; and injury at the inferior radio-ulnar articulation, about 1 per cent. Where the shafts of both forearm bones are injured the direction in the radius is transverse in all the cases examined.

Position of Injury.—By far the commonest is half an inch above the lower end of the bone. It is striking that 99 per cent of the injuries recorded are three-quarters of an inch or less from the lower end.

Displacement of Fragment.—This is backward in 74 per cent, forward in 2 per cent, and there is none in 24 per cent, but most of the cases examined had been manipulated by the surgeon, so displacement is more or less misleading. Outward and inward rotation and displacements are not recorded, as many of the cases showed rotation, chiefly outwards, but it was often difficult to decide which to include and which not.

(*b*) *The Ulna.*—Some part of this is injured in 49 per cent of the total number of cases, about one-half the frequency of the radius. Injury to the styloid process occurs in 46 per cent of the total number of cases, so that by far the commonest injury to this bone in this series is here. It is interesting to contrast the frequencies with which the styloid processes of the ulna and radius are damaged. In the former 46 per cent and in the latter 3 per cent show fracture of these processes, and we think the explanation is due partly to the styloid of the radius being structurally stronger than that of the ulna, partly because the fragment of the radius being most commonly displaced backwards and rotated outwards, the internal lateral ligament attached to the apex of the ulnar styloid is put on the stretch, and must either rupture or exert tension on that process, while at the same time, with the fragment of the radius rotated outwards, the interarticular fibro-cartilage attached to the base of the ulnar styloid pulls on that base and helps to damage it.

Direction of Injury.—There is no tendency towards any one type, nor is there any predominant type in this bone when the shafts of both forearm bones are damaged. That no tendency has been noted is perhaps because the injury is relatively rare and a sufficient number of cases has not been examined.

Position of Injury.—All are within 2 inches of the lower end, and so, on the whole, extend farther up the shaft than in the radius. As would be expected, the majority are at the styloid process, 94 per cent.

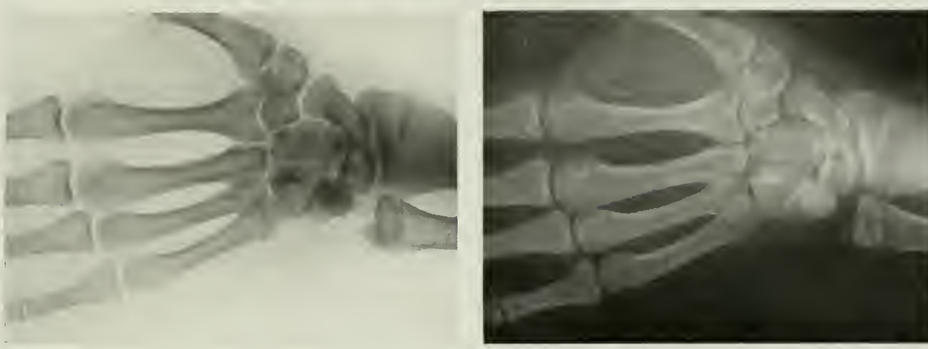
Displacement of Fragment of the Shaft.—This is chiefly backwards, as in the radius, though, owing to a fracture in some cases being continued up from the styloid process, the frequency with no displacement is also high.

Fractures of the Bones of the Hand

Fracture of the Carpal Bones.—Any of these may be fractured, examples being met with in routine examination. Injury is present in one or more of these in 13 per cent of the total number of cases described above. This proves how frequently these are damaged in wrist injuries, and probably the frequency is even greater, as only undoubted cases of injury are included. The carpus without either of the forearm bones is injured in 5 per cent of cases, the carpus and radius in 4 per cent, and in none is the carpus injured with the ulna only, showing that the ulna does not directly take part in the mechanism of the wrist-joint. The carpus, radius, and ulna are together injured in 3 per cent of cases. The scaphoid is the one most frequently

a

b



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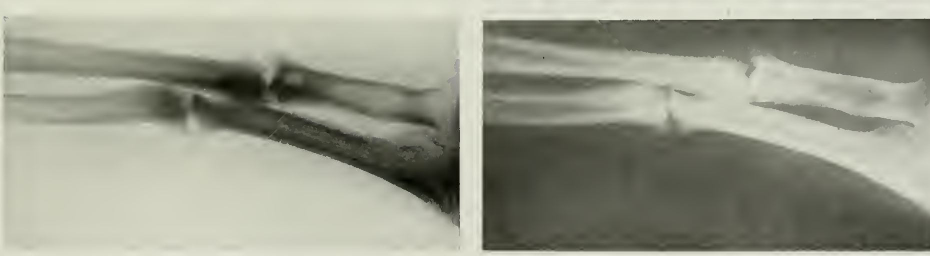


PLATE XXVIII.—FRACTURES IN FOREARM, WRIST, AND HAND.

a, Fracture of terminal phalanx of thumb, backward displacement. Lateral and antero-posterior views.
b, Fracture of trapezium.
c, Fracture through lower end of shaft of radius, very little displacement.
d, Non-union fracture of radius and ulna, formation of false joints.

a b c d e f

PLATE XXIX.—FRACTURES AT WRIST-JOINT.

Fracture of lower end of radius. *a*, Lateral view showing displacement. *b*, Antero-posterior view showing nature of fracture.

c, Antero-posterior view of separated epiphysis of lower end of radius. *d*, Lateral view to show displacement.

e, Fracture through lower end of radius. *f*, Colles's fracture, antero-posterior view.

a *b* *c* *d*

PLATE XXX.—FRACTURES OF WRIST AND HAND.

PLATE XXXI.—NORMAL HIP, DISLOCATION, AND FRACTURE AT HIP-JOINT.

a, Normal hip-joint, showing the head of the femur; the shadow of the acetabulum is seen surrounding part of the head.

b, Hip-joint showing dislocation upwards of head of femur.

c, Fracture through neck of femur (intracapsular).

a

b

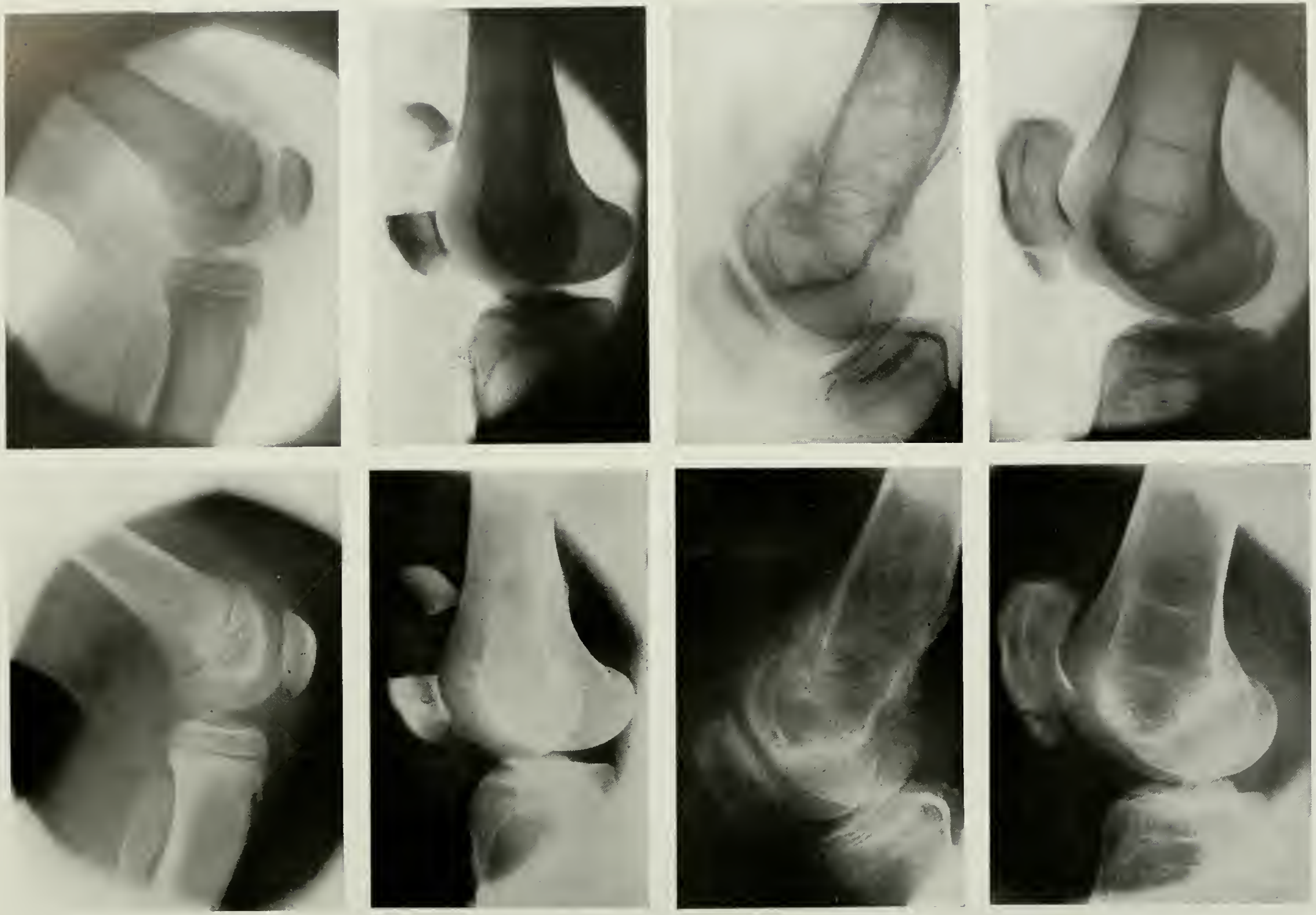
c

PLATE XXXII.—Injuries and Disease of Pelvis and Hip-joint.

a, Fracture of pelvis in a child ; the injury has occurred at both pubic bones, and on one side through the ischium.

b, Fracture of neck of femur, impaction into great trochanter.

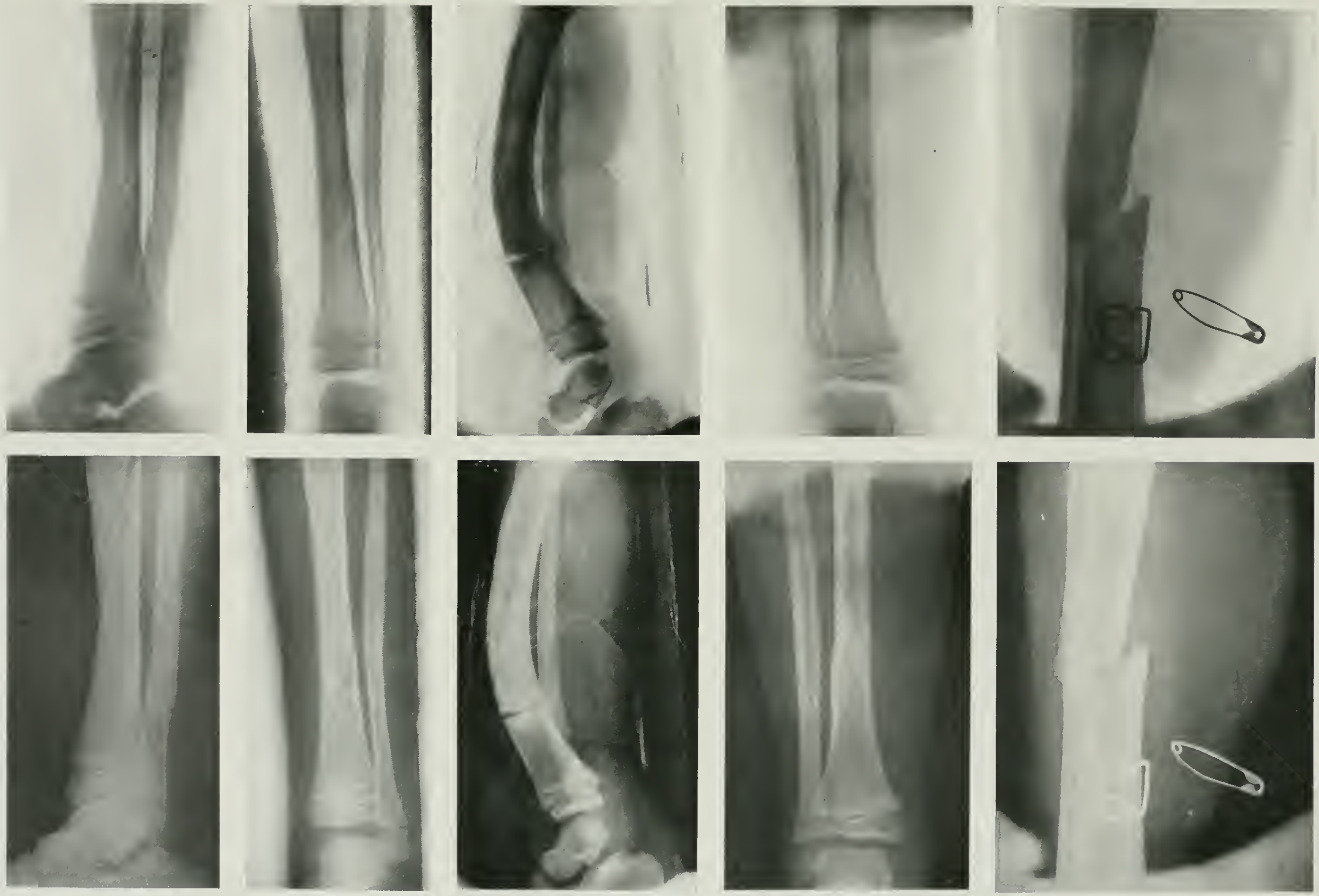
c, Displacement of upper end of femur in a child. The acetabulum is eroded and the head of femur is absent. This is probably the result of tuberculosis. The appearances are somewhat similar to those of congenital dislocation.



a *b* *c* *d*

PLATE XXXIII.—Injuries at Knee-joint.

a, Knee-joint showing epiphyses, chronic inflammatory changes at epiphysis of tibia (Schlatter's disease). *b*, Fracture of patella, fragments widely separated. *c*, Fracture of lower end of femur. *d*, Fracture of lower edge of patella.



a *b* *c* *d* *e*

PLATE XXXIV.—FRACTURES OF BONES OF LEG.

a b c d e

PLATE XXXV.—FRACTURES AT THE ANKLE-JOINT.

a, Oblique fracture through lower end of fibula. Lateral position.
b, Fracture of internal and external malleoli, displacement of foot outwards at ankle-joint.
c, Fracture of astragalus. *d*, Fracture dislocation at ankle-joint. Antero-posterior position.
e, Fracture lower end of fibula.

damaged, no less than thirteen times out of nineteen. Next in order is the trapezium, while the carpal bones towards the ulnar side are less frequently involved.

Fig. 223.—Three illustrations of Colles fracture, taken at different dates to show progress of repair.
a. May 1, 1915. b. Jan. 28, 1916. c. June 18, 1916.

Fractures of the Metacarpal Bones are common. Perhaps the most frequently met with is that of the base of the first metacarpal (Bennet's fracture).

Fractures of the Phalanges are also common. There may be no displacement in some fractures. The diagnosis can be made by a screen examination, but even with these small bones it is always well to confirm the diagnosis by taking a radiograph. A negative diagnosis should never be made on the screen examination alone.

Fractures of the Pelvis

The pelvis is often injured by direct or indirect violence. A radiograph should be taken of the whole pelvis in one picture, or several smaller ones may be taken to discover the nature of the injury. The position usually chosen is the antero-posterior, that is, with the plate behind and the tube in front.

The iliac bones may be fractured, when it is sometimes difficult to show the seat of the lesion. When the sacrum is damaged, there may be a fracture at the sacro-iliac synchondrosis, and the body of the sacrum may also be involved in these injuries. The pelvis is often damaged when the violence is of a crushing type, or it may be broken by direct violence. The ischium may also participate in the injury. The coccyx is frequently fractured.

In all doubtful cases both sides of the pelvis should be examined, and the hip-joints should also receive attention. The common injuries are easily distinguished, but there are many grades of fracture, where the injury may not be demonstrable if only one radiograph be taken.

Injuries near the Hip-joint

In some cases of injury at the hip-joint a widening of the interarticular space may indicate an **effusion of blood** into the joint, which later on may lead to inflammatory changes and abscess formation.

An uncommon injury to the hip-joint has been recorded, where the head of the bone was driven through the **acetabulum** into the pelvic cavity. Or the acetabulum may be fractured to a lesser degree. This may be shown on examination.

The Neck of the Femur is frequently broken when, especially in old people, there may be impaction. Traumatic coxa vara is a fairly common occurrence. Fractures of the neck of the femur for clinical purposes are divided into those near the head and those involving the base near the trochanter.

Fracture of the neck of the femur near the head; the so-called intracapsular fracture is most frequently met with in old persons.

Fracture of the neck near to the great trochanter, the so-called extracapsular fracture. This, however, nearly always involves the joint, as the capsule extends along the bone to the shaft and completely covers the neck. The line of fracture may, however, be extra-capsular behind. Radiographically, it is sometimes difficult to arrange fractures in this region strictly under one or other head, as in a number of cases the fracture extends beyond the limits of both. Fracture of the neck of the femur in healthy individuals is generally due to a considerable degree of violence. There are exceptions to this in the aged and even in young and apparently healthy adults. A fracture may be discovered when patients are examined after quite minor degrees of violence. In one case of this kind a young soldier, while quietly walking, felt "something give way." On examination a fracture of the neck of the femur was revealed.

Fig. 224.—Fracture through shafts of both femora. The fracture is comminuted on the left side.

Fracture through the Great Trochanter is also common. It may be localised to the trochanter or may extend downwards obliquely into the shaft.

Fractures of the Femur

Fracture through the Shaft below the lesser trochanter is an injury often met with.

Fractures of the Lower End.—(1) *Transverse supra-condyloid fracture* is practically identical with that involving the lower third of the femur.

(2) T- *or* Y-*shaped fracture* of the condyles. In this a transverse fracture is complicated by a fissure which runs into the joint, separating the two condyles.

(3) *Separation of either condyle* usually results from direct violence, the line of fracture being oblique.

(4) *The lower epiphysis* of the femur is separated from the shaft in young people.

(5) *Longitudinal and spiral fractures* running down to the knee-joint are met with in the femur.

Fractures of the Patella

These may vary from mere fissures to complete fracture with wide separation at the line of fracture. The partial fracture is the one which it is most important to recognise. A lateral view of the knee-joint is the most useful position in which to radiograph the joint for its recognition.

Fractures of the Bones of the Leg

The tibia and fibula may be involved when there is a fracture of the lower end of the femur; they may be broken together or either bone by itself. Fractures of the shaft of the tibia and fibula may vary from a fine crack to a marked degree of fracture, with displacement of the fragments. The tibia is frequently the seat of aspiral fracture. The fibula only may be fractured, when there is no marked displacement or external sign of fracture.

Fractures in the Neighbourhood of the Ankle-joint

These are usually produced by indirect violence. There may be marked displacement of the foot. Generally the line of fracture runs obliquely from above downwards and forwards through the malleolus, less frequently the fracture is situated in the position described by Pott, *i.e.*:

(1) **Pott's Fracture.**—The fibula is generally broken three inches above the tip of the external malleolus, and the fracture is transverse, the upper end of the lower fragment being displaced inwards towards the tibia, while the foot is displaced outwards. The tip of the internal malleolus may be broken off.

(2) **Dupuytren's fracture** shows the following condition: well-marked outward displacement of the foot along with the lower fragment of the fibula, the internal malleolus being torn off and displaced outwards with the foot.

(3) **The fibula** shows the usual type of fracture, associated with an almost transverse fracture of the tibia just above the base of the internal malleolus.

Fracture of the Os Calcis is a comparatively common injury, the result of direct violence. The degree of damage to the bone varies from a crack to a severe crushing of the bone.

Fig. 225.—Fracture of os calcis (gunshot wound).

Fracture of the Astragalus.—The lesion is often a severe, comminuted one. Both bones may be broken when a patient lands heavily on both feet; and these fractures are often associated with fracture of other bones of the foot. Any of the tarsal bones may be fractured. The extent of the injury is often difficult to determine. It may be merely a crushing of the bone, in which case it is not easy to distinguish the injury from changes which are the result of disease, or there may be a distinct line of separation.

The metatarsal bones are frequently involved in injuries to the foot. Fractures may be transverse or longitudinal. Fissured fracture of the bone is not uncommon.

The phalanges are also frequently injured. Two positions of the foot should always be taken when looking for fractures. Stereoscopic pictures are very helpful in doubtful cases.

PLATE XXXVI.—FRACTURES OF LEG, ANKLE, AND FOOT.

a, Oblique fracture of shaft of tibia, lateral view, shows epiphyses of lower end of tibia and also of os calcis.

b, Antero-posterior view of tibia and fibula, showing an oblique fracture of shaft of tibia; and also epiphyses at lower end of tibia, fibula, and os calcis.

c, Fracture through shaft of femur; the bone is rarefied and is probably the seat of secondary carcinoma.

d, Fracture of lower end of tibia and fibula, forward dislocation of tibia.

e, Fractures of tibia and fibula; note nature of fracture of tibia.

f, Fracture of bases of second and third metatarsal bones.

a b c d e

PLATE XXXVII.—CHRONIC INFLAMMATORY CONDITIONS OF BONES.

a, Osteitis of lower end of femur, sequestrum formation. *b*, Osteitis with superficial periostitis. *c*, Osteomyelites of femur, periostitis with new bone formation. *d*, Osteitis and periostitis with abscess formation in soft parts (traumatic); note small piece of detached bone in abscess. *e*, Extensive osteitis and periostitis, probe in sinus; lower end of femur.

DISEASES OF BONE

All varieties of bone disease are met with in the radiographic examination of the bones, it being possible to trace the progress of disease from the slightest beginnings to the most advanced stages. A thorough appreciation of the normal appearance of bone is necessary before we can make out departures from it. Good negatives are essential, that is, the negative must show the finer detail as well as the outline of the bone. Soft tubes give better plates for this purpose than hard ones, but the exposures require to be longer, and this is in some cases a disadvantage, as movement on the part of the patient is apt to spoil the picture. When a long exposure is necessary the limb may be kept quite still by laying sand-bags around it and upon the parts not required in the picture, or soft pads may be placed on the limb, and a compression apparatus fixed lightly down upon them. The use of a cylindrical diaphragm gives sharper radiographs by cutting off the secondary radiations. When practicable it is better to place the X-ray tube as far away from the plate as possible, a distance of three feet (or more) giving the parts with less distortion. When a particular bone has to be examined it is a good plan to get the corresponding one on the healthy side for comparison, taking care that both bones are radiographed under the same conditions of tube and distance, and the limb in the same posture.

A brief consideration of the pathology of bone is necessary in order to understand clearly the various conditions met with in the course of examination of bone disease. Many different terms are applied more or less loosely to the pathological processes, and much confusion is introduced thereby.

Necrosis.—Necrosis or death of bone may occur in a variety of forms, and from many different causes:

(1) Acute localised suppurative periostitis, the sequestrum or dead mass being then simply a superficial plate or flake of the compact interior.

(2) Acute infective osteomyelitis, the sequestrum then often involving the whole thickness of the bone, and invading more or less of the diaphysis.

(3) Acute septic osteomyelitis, usually traumatic in origin, the sequestrum being annular in shape, and involving more of the interior of the bone than the exterior.

(4) Acute or subacute septic osteitis of cancellous bone, the sequestrum consisting of small spiculated fragments of the bony cancelli which have escaped absorption by the granulation tissue which always forms in such a process.

(5) Tuberculous disease of cancellous tissue, the sequestrum being light and porous, often infiltrated with curdy material, and rarely separated completely from the surrounding parts.

(6) Syphilitic disease of cancellous or compact bone, usually resulting from excessive sclerosis, or gummatous disease of the periosteum, which has become septic.

(7) The action of local irritants, *e.g.* mercury and phosphorus.

Caries or Osteo-porosis, or rarefaction of bone, a clinical condition resulting from inflammation, and consisting of a soft and spongy condition of the bone.

(1) Caries sicca, when the process occurs without suppuration.

(2) Caries suppurativa, when pus is always present.

(3) Caries fungosa, when granulation tissue is always in excess, especially in tuberculous disease of the articular ends of bones.

(4) Caries necrotica.—Necrosis is associated with caries, the sequestra consisting of spiculated fragments, or in tuberculous disease of larger masses.

Sclerosis of Bone is usually the result of some chronic inflammatory infection :

(*a*) Chronic periostitis, whether simple or syphilitic.

(*b*) Chronic osteomyelitis, simple, tuberculous, or syphilitic.

(*c*) Chronic osteitis of the compact bone, which is always secondary to a case of the former.

Classification of Inflammatory Affections of Bone

(1) Periostitis.—(*a*) Acute localised, with or without suppuration.

(*b*) Acute diffuse, always associated with, or secondary to, acute infective osteomyelitis.

(*c*) Chronic simple, or hyperplastic.

(*d*) Chronic tuberculous.

(*e*) Chronic syphilitic.

(2) Osteitis of Compact Bone, which is always associated with, and secondary to, either periostitis or osteomyelitis, and so will not be described separately. The acute form results in necrosis, the subacute in osteo-porosis, and the chronic in sclerosis, except in tuberculous disease.

(3) Osteomyelitis, or inflammation of the medulla of long bones.

(*a*) Acute septic (traumatic).

(*b*) Acute infective (idiopathic), acute panostitis.

(*c*) Subacute simple or infective, *e.g.* after fractures, or during the separation of sequestra, resulting primarily in rarefaction, but finally in sclerosis.

(*d*) Chronic simple, tuberculous or syphilitic, usually causing general enlargement and sclerosis of the bone, even if locally some rarefaction is present.

(4) Osteitis of the Cancellous Tissue may similarly be :

(*a*) Acute septic or traumatic.

(*b*) Acute infective.

(*c*) Subacute simple or septic.

(*d*) Chronic simple, syphilitic, or tuberculous.

When limited to the articular end of a bone in a young person, this is sometimes termed epiphysitis.

Acute Inflammation of Bone

Acute Localised Periostitis generally arises as a result of traumatism, with or without an open wound ; but it may be caused by an infective process such as rheumatism, or by direct extension of an inflammatory process such as abscess. It may end in an inflammatory swelling of the surface of the bone, which later may cause a superficial abscess. A thickening of the soft parts over the bone may be shown. Resolution may follow this, and a localised thickening at the seat of inflammation may remain for some time. If suppuration occurs and pus forms, it may be possible to demonstrate its presence radiographically.

Superficial Necrosis may be a result of localised periostitis. This is characterised by the separation of small particles of dead bone. New bone may be thrown out around the inflamed area, and leave evidence in the form of layers of more or less dense bone.

Acute Infective Osteomyelitis.—Acute necrosis occurs generally in children of low vitality, often of tubercular inheritance. The early manifestations of this disease are often extremely slight. A hardly perceptible inflammatory process in the neighbourhood of the epiphyseal line or near a joint rapidly spreads, involving the whole diaphysis of the bone. A subperiosteal abscess may form, while the central portion of the bone escapes almost entirely. Should the process commence in the vicinity of the epiphyseal line it may spread in several directions, may involve the medullary cavity, and give rise to the most typical form of osteomyelitis. Necrosis follows, usually implicating the whole thickness of the medullary cavity and diaphysis, and sometimes extending its whole length. Occasionally the neighbouring joint becomes involved. The pictures presented by this disease show all stages, from a preliminary inflammatory process, to advanced necrosis, formation of sequestra, and new bone formation. If radiographs are taken at regular intervals, the whole process of inflammation, suppuration, necrosis of bone, sequestra formation, deposit of new bone around the dead bone, and the gradual building up of new bone after operation to remove the sequestra may be followed, and an interesting and instructive series of plates be obtained.

The pathology of this form of disease of bone may be watched by means of radiography. The demonstration of the presence of free bone in a cavity surrounded by new bone is a guide to the surgeon in the operation as to when and where to operate, and indicates clearly the progress the bone is making in the direction of recovery.

Acute Septic Osteomyelitis.—This arises as a result of infection from without, in cases of compound fracture, and after amputation or excision of bone ; the shafts of long bones are affected, and the disease generally runs a rapid course.

Chronic Inflammation of Bone

Chronic osteo-periostitis, a chronic inflammatory process, results in overgrowth, thickening, and condensation, (1) as a localised chronic periostitis, traumatic, rheumatic, or syphilitic in origin ; or (2) as a diffuse form, usually tubercular or syphilitic, which tends to involve the whole bone. It may result in a small abscess or central necrosis. Around this focus the bone may become greatly thickened. Examples of this are shown in Plate XXXVII., Figs. *d* and *e*.

Typhoid Osteitis.—The typhoid bacillus may lie dormant for years without causing any abscess formation. The appearance is typical, and

Fig. 226.—Typhoid osteitis and periostitis resulting in an abscess.

Fig. 227. — Elbow-joint showing disease. Formation of new bone along shaft of ulna and humerus. Chronic osteitis and periostitis, probably tuberculous in origin.

is shown in Fig. 142. The disease may show itself in the spine subsequent to typhoid fever. The joint in the vicinity of the bone may become involved. (See Plate XXXIX. *d*.)

Tuberculous Disease of Bone.—This form of disease of bone is frequently met with in X-ray examinations. Bones may be affected in two ways by tuberculosis. The periosteum or the cancellous tissue may be primarily involved.

Tuberculous Periostitis, or specific inflammation of the periosteum, is met with. Caseation and suppuration are likely to follow, frequently leading to the formation of abscesses, and, later, of discharging sinuses. The inflammation may result in a thickening of the layers of bone and a shutting in of the products of suppuration, hence, if situated near a joint, the pus may burrow under the dense bone and invade the joint.

Tuberculous Osteitis always arises in cancellous tissue, and it affects the short bones or the shafts or ends of the long bones. The short bones of

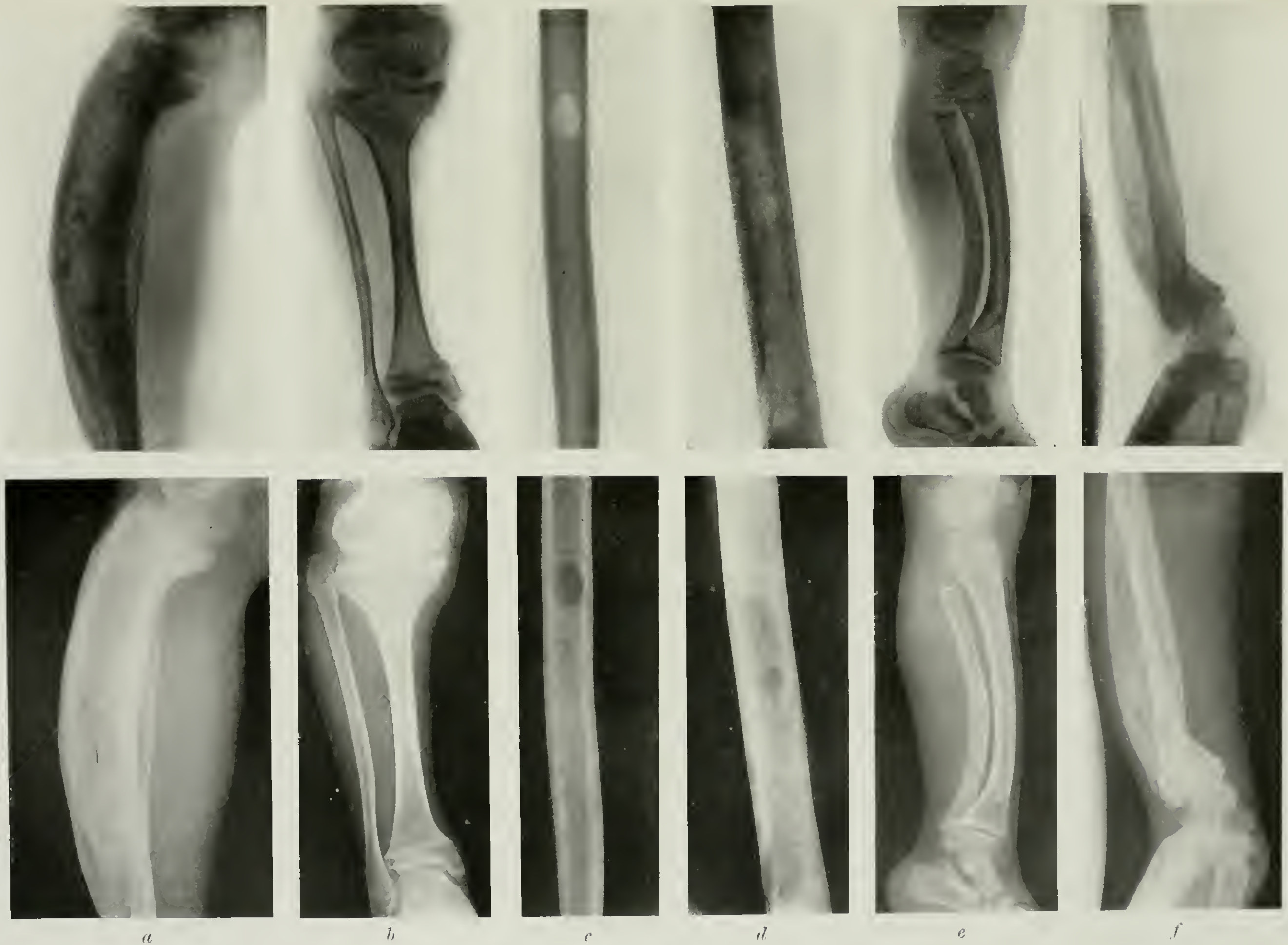


PLATE XXXVIII.—INFLAMMATORY AND OTHER AFFECTIONS OF BONES.

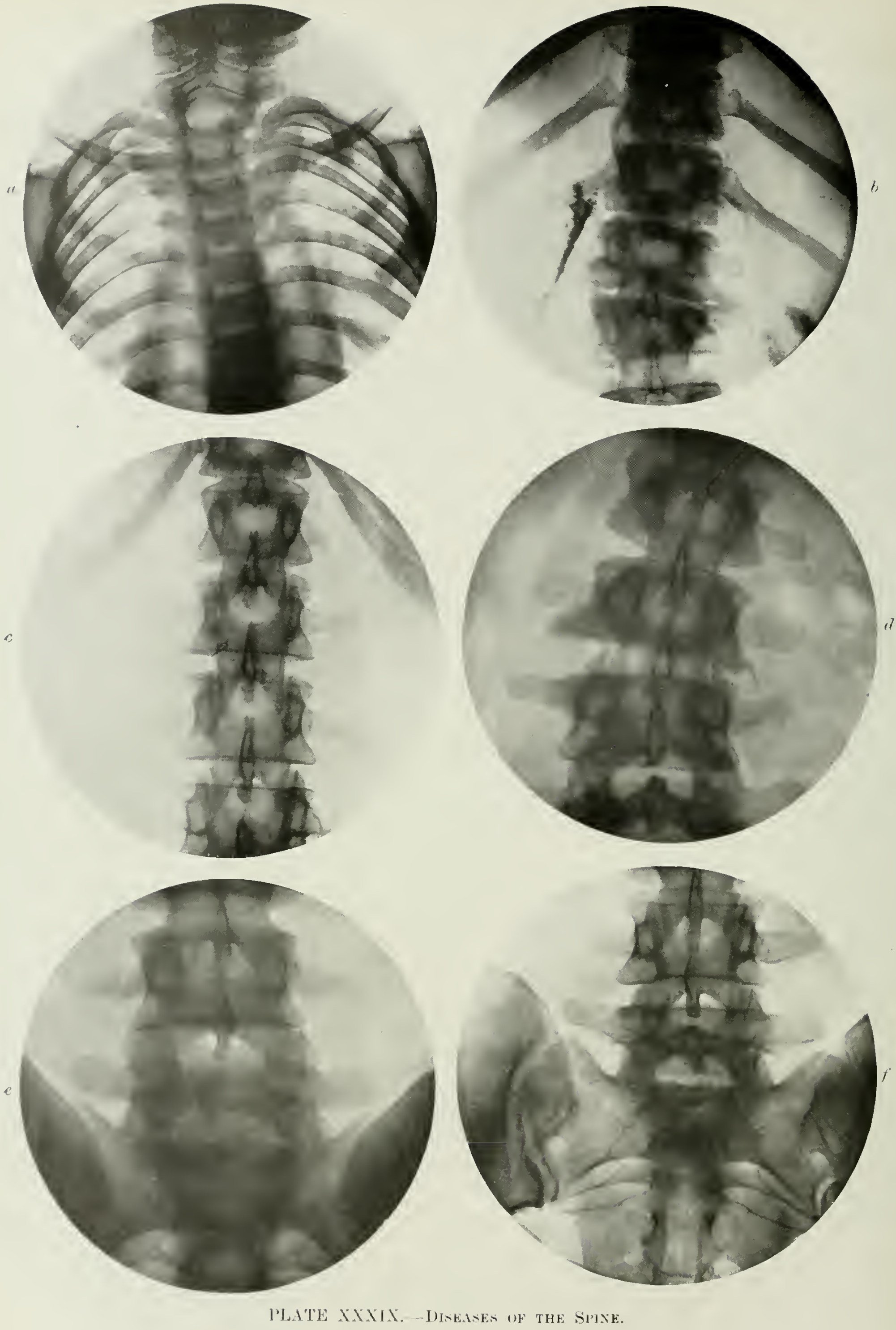


PLATE XXXIX.—DISEASES OF THE SPINE.

a, Healed caries of cervical spine.
b, Caries of spine involving last dorsal and first and second lumbar vertebrae.
c, Normal lumbar spine.
d, Chronic changes in lumbar spine. The joint between third and fourth lumbar vertebrae is distended. A history of enteric fever suggested the possibility of a post-typhoid arthritis.
e, Fracture of transverse process of fourth lumbar vertebra on right side.
f, Early sacro-iliac disease on right side.

the hands and feet are liable to this condition, especially in children. When the phalanges are involved the condition is known as tuberculous dactylitis. The typical appearance of this condition is shown in Plate XLI., Fig. *c*. Several bones may be simultaneously affected. Some slight injury may determine the development of tuberculous periostitis or osteitis.

Tuberculous Epiphysitis.—An inflammation affecting primarily the epiphyseal line and adjacent bone. The tendency is for it to spread and involve the joints by the invasion of the synovial membranes. Separation of the epiphysis may result. The adjacent bones show a condition of osteitis and periostitis. Abscess of bone, more common in adults than in children, may result. Chronic abscess in the head of the tibia is somewhat frequent. The characteristic symptom of deep aching pain calls attention to the possibility of bone abscess. The bone around the abscess cavity is frequently very dense, though it varies in this respect in parts of its circumference. Radiographically, the condition may be recognised by an increase in shading and loss of detail in the bone structure on the surface. The periosteal outline is blurred, and may show patches of caries or collections of pus. The soft parts are frequently involved in the inflammatory process, and a soft puffy swelling may be seen over the affected portion of bone. When the disease has advanced, the original focus of disease shows up as a lighter area, with patches of rarefaction of bone leading from it. The fine detail of the bone is lost, and a general haziness is left in its place. Later, when pus has formed, an irregular abscess cavity can be seen, there being as a rule very little condensation of bone round the abscess. Should the cancellous tissue in the neighbourhood of an epiphyseal line be involved, the disease extends through the line, and affects the epiphysis, which shows as a spongy rarefaction with irregular edges. The inflammatory process spreads into the joint itself, and sets up a synovitis, which is characterised by a general distension of the joint and an obscuring of detail.

Syphilitic Disease of Bone.—The osseous tissue may be involved in acquired syphilis in either the secondary or tertiary form. Syphilis of the bone is frequently met with, and it is often difficult to differentiate it from a simple inflammatory process. Chronic thickenings in the form of nodes are diagnostic of *syphilis*. When a considerable extent of bone is involved, it may be difficult to distinguish between this condition and an early stage of malignant disease. In the latter the disease spreads more rapidly, and the characteristic appearances of malignancy manifest themselves. In the tertiary period the bones may participate in the changes which involve any and every tissue of the body. These consist of an infiltration and overgrowth of the connective tissue, which, if diffused through the organs, produce sclerosis, or, if localised to one spot, lead to the formation of a gumma. The *subperiosteal gumma* may be met with. It probably results from caries of the adjacent bone, and if it extends widely an extensive area of bone may become eroded and irregular. The skull is the part most frequently involved in these changes, and may show a curious worm-eaten appearance. The formation of gummata, several of which may break down, gives a curiously uneven appearance to the radiograph of the skull, thickening and enlargement, alternating with broken-down tissue, leading to marked thinning of the bone in places.

Congenital Syphilis.—Nodes, known as Parrot's nodes, form on or around the anterior fontanelle. The newly formed bony tissue becomes sclerosed and dense, and deformity may then persist through life. A similar condition is met with in the shafts of the long bones, due to the alternating deposition of lamellæ of soft and hard bone outside the ordinary compact bone.

Syphilitic Epiphysitis.—This condition is characterised by enlargement of the ends of the bones. It is met with in infants, and somewhat resembles rickets, but comes on at an earlier date. The enlargement is situated mainly in the epiphyses, but not uncommonly extends some way along the shaft, thus contrasting forcibly with rickets. The change commences at the zone of calcified cartilage nearest the diaphysis, which becomes friable, thick, and irregular, and may become transformed into granulation tissue as the disease progresses. Later, reparation of the epiphysis may follow. The disease is usually symmetrical and often multiple. A symmetrical overgrowth of the tibia, combined with an anterior curvature, often occurs in syphilitic children, resulting in permanent deformity of the legs.

Craniotabes.—A condition characterised by localised absorption of the osseous tissue of the cranium, leaving small areas where the bone is thinned or absent. Radiographically, these are often met with.

Actinomycosis.—Though comparatively rarely seen in the human subject, the condition should not be altogether ignored as a source of disease of bone. The lower or upper jaw may be involved, the appearances presented being somewhat similar to those of tuberculosis ; the tendency in the early stages is toward hyperplasia of bone, with considerable increase of the periosteal element ; later on necrosis may supervene and a persistent sinus occur. An examination of the pus should always be made in doubtful cases. Other parts of the body likely to be involved are the ribs and sternum ; when the pleura or lung are involved, the spine may become invaded secondarily to the lung and mediastinal infections, when abscess formation may first call attention to the disease.

Fig. 228.—Wrist and hand of child, showing changes in lower end of radius and ulna due to rickets.

Rickets.—The chief changes are found in the neighbourhood of the epiphyses ; the epiphyseal cartilage is enlarged, thickened, and irregular; there is an increase in the cartilaginous elements of the bone, and a delayed ossification; the bones are weaker and less rigid, and become deformed in consequence. The ossifying process is delayed. Changes in the shape of the bones of the head may be detected, and the spine may be affected by kyphosis; the teeth do not erupt till late, and are stunted. Changes in the ribs are produced by enlargement of the costochondral junctions (beaded ribs), which when present on both sides of the sternum produce what is known as the rickety rosary. The principal changes met with radiographically are at the epiphyseal lines of the long bones and the adjacent joint.

Achondroplasia.—A curious congenital condition, resembling rickets, in which the growth of the osseous tissue on the shaft side of epiphyses of the long bones of the arm and of the leg is affected, so that the limbs are short and stunted, and the stature correspondingly diminished, although the epiphyses are normal.

Leprosy of Bone.—This disease frequently affects the bones and joints. A case has been described where the X-ray appearances of the bones gave the clue to the diagnosis.[1]

Simple Atrophy of Bone.—This results from a variety of conditions, quite independent of rarefying inflammation, in which it is a marked feature. It may be congenital, or may be due to:

(*a*) Interference with the epiphysis, as in rickets, or injuries, or as a sequence to tuberculosis or other inflammation, involving the junction of the cartilage.

(*b*) Injury or disease of the nervous system or of peripheral nerves, as tabes dorsalis, syringomyelia, leprosy, etc.

(*c*) Want of use, as in a paralysed limb, or following upon ankylosis of a joint.

(*d*) Local pressure, caused by a tumour growing within or outside the bone.

(*e*) A senile change.

These conditions are illustrated in many of the skiagrams showing disease of bone and joints, and attention is called to them as they occur.

Mollities Ossium or Osteo-malacia.—A condition characterised by the absorption of the osseous substance of the bones, as a result of which softening and rarefaction are produced, followed by bending or spontaneous fracture. Pathologically there is a replacement of the medullary substance by a soft, fibro-cellular tissue, which is exceedingly vascular, and into which hæmorrhage may occur. The bony cancelli are absorbed, and also the greater part of the compact tissue. The earthy salts may be absorbed to about one-sixth of the normal amount, but the relative percentage of phosphate of lime to the carbonate is not changed. The bone substance remains for a time in a decalcified state. It has been suggested that an acid, probably lactic acid, is the agent which dissolves the earthy salts. The process may

[1] "A Case of Leprosy diagnosed by X-Rays." Major A. Neve, M.R.C.S.E. *British Medical Journal*, December 1915.

be due to the absorption of an internal secretion, normal or abnormal. The condition is interesting in connection with a number of others where the process appears to follow a similar course. It has been observed that when, as a result of malignant disease, secondary changes occur in bones, particularly in cases of carcinoma of the breast, the changes are of this type, the bone in places showing areas which offer less resistance to the X-rays, and are consequently represented by lighter shadows in the negative. There may be sharply punched out areas appearing in the shadow of the normal bone. It is probable that these changes are of a similar nature to those seen in mollities ossium, and the explanation given in the latter may apply to the malignant type. Possibly an internal secretion may lead first to decalcification of the affected areas, followed later by partial absorption of modified bony tissue, the remainder showing in the bones as areas of varying density. The cases observed have been remarkable for the large number of bones involved, which may be taken as an indication that the changes are due to a general rather than a local cause, while there may be very little in the way of symptoms beyond deep-seated pain. Such conditions offer a large field for investigation by means of radiography. Attention may be called clinically to a condition of this type when a spontaneous fracture, or fracture from slight violence, occurs. The changes in the bone can often be shown radiographically.

Morbid Conditions of Bone which predispose to Fracture.—It is important to bear well in mind several conditions of bone which predispose to fracture. When fracture from slight violence occurs, suspicion should at once be aroused, and the examination should be conducted on lines which will enable the radiographer to show not only the fracture, but also the condition which has predisposed to it. For this, good negatives are essential. A picture which will show a fracture is often not full of fine detail, without which no opinion on bone disease can be formed. In the same way a screen examination will show a fracture, but an opinion of the bone condition cannot be formed from it. The most usual conditions predisposing to fracture are :

(1) Atrophy of bone. This may be senile, or due to disease, *e.g.* ankylosis of a joint or certain nervous affections.

(2) Fragilitas ossium. This consists in an inherited tendency to spontaneous fracture, occurring in children and adults.

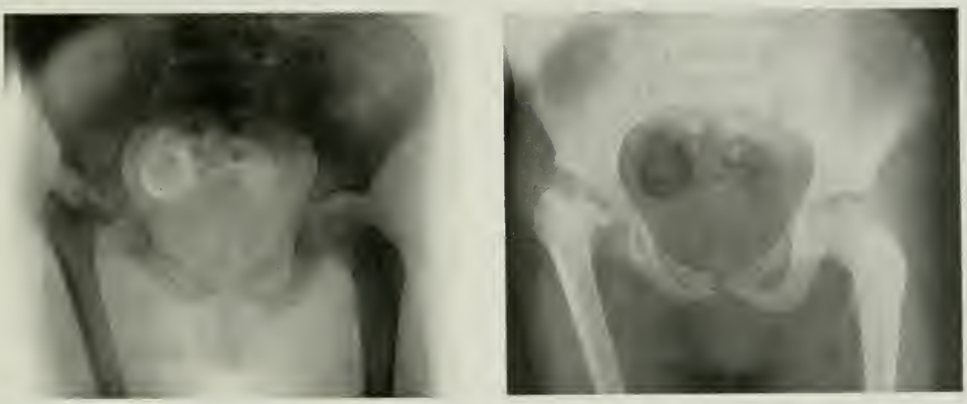
(3) Bone disease, such as tuberculosis, rickets, syphilis, osteo-malacia.

(4) Local bone disease or tumours, such as sarcoma, secondary carcinoma.

A condition which frequently leads to fracture is a cystic disease of bone. Many examples have been shown of late years occurring in the long bones, the humerus being a common seat of this tumour. It is frequently a very slow form of myeloid sarcoma. Elmslie has drawn attention to this cystic disease of bone, and shown several interesting examples.

a

b



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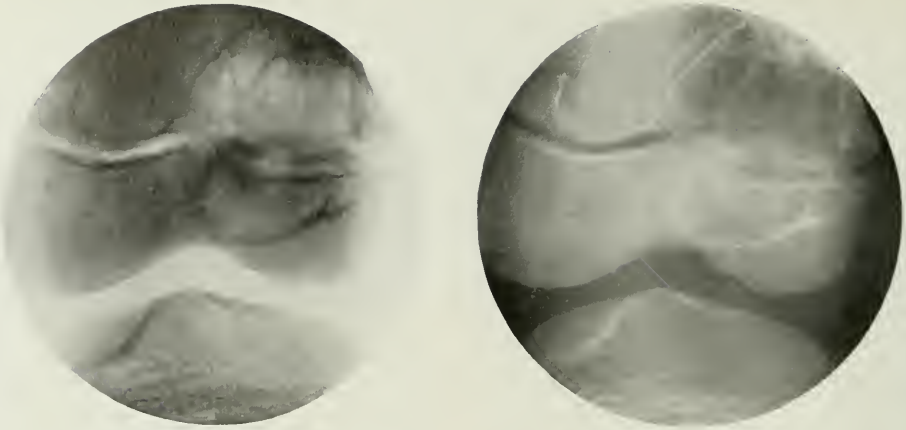
[PLATE XL.—TUBERCULAR DISEASE OF THE HIP-JOINT.

a, Tubercular disease of hip-joint affecting chiefly the upper part of acetabulum.

b, Tubercular disease of hip, absorption of head and greater part of neck, upward displacement of femur. (Radiograph by Dr. Salmond.)

c, Later stage of tubercular disease of hip-joint, disorganisation and displacement of head, large abscess on outer side of shaft of femur.

a



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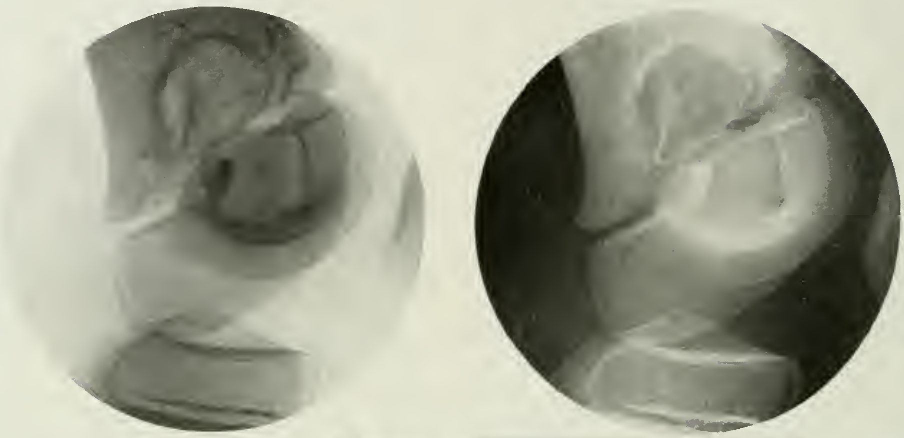

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PLATE XLI.—TUBERCULAR DISEASES OF JOINTS.

a, Tubercular disease of lower end of femur, involving diaphysis and epiphysis, a considerable degree of sclerosis of bone around an abscess cavity.

b, Lateral view showing the same changes. (Radiographs by Dr. R. W. A. Salmond.)

c, Tubercular area in scaphoid. (Radiograph by Dr. R. W. A. Salmond.)

d, Tubercular disease at ankle-joint; note rarefaction of bones of foot.

DISEASES OF JOINTS

These are numerous, and have characteristic appearances which may often be shown by radiography. A great deal of light has been thrown upon the differential diagnosis of such conditions as tuberculosis of joints, chronic arthritis, gout, and other diseases by the systematic examination of joints at regular intervals during the progress of the disease. The various forms of arthritis may be distinguished one from the other. Acute inflammation of a joint may be shown when the synovial sac is seen fully distended ; later the shadows caused by the fluid will become denser when pus forms. The changes in cartilage, especially when the disease is chronic, are seen, and later the bone may become affected. Radiographically the interspaces between the cartilages are increased when the joint is full of fluid. The opposite limb, when healthy, should also be taken in order to determine departures from the normal.

Tuberculous Disease of Joints

In this disease when at all advanced the departures from the normal are marked. The synovial membrane becomes swollen and pulpy. The joint may be very much enlarged, this being shown when the joint is radiographed, variations in the density of the shadows of the soft parts indicating an inflammatory change in the synovial membrane. The cartilage becomes eroded, and later the process extends to the bone itself, which may show rarefied areas, and when these break down they show erosions. In places irregular thickenings of the bone also occur, and the bone in the vicinity of a joint may be thickened for some distance up the shaft. In the later stages the joint shows marked disintegration, with a synovial cavity filled with caseous material, this showing in the radiograph as faintly marked irregular shading within a greatly swollen joint.

The surrounding bones, especially those below the joint, show atrophic changes. All the bones entering into the joint become affected. All stages in the history of tuberculous disease of joints may be demonstrated by radiography. The very early stages are, however, the most difficult on which to give an opinion, and clinical evidence should always be taken into account when an opinion is required. It is of the utmost importance to be able to determine the presence of early tuberculosis, for on that the future treatment depends. In joints which have been the seat of recent injury, changes due to the injury may be detected, and these may later become the centre of a tuberculous infection. Consequently, when examining joints after injury it is important to be able to distinguish fine changes in the parts.

The later stages of tubercular disease are much easier to recognise; rarefaction, caseation, and formation of pus are readily distinguished. A localised rarefaction of bone in the neighbourhood of a joint should arouse suspicion of the presence of pus, particularly when the bone round the rarefied area shows a tendency to condensation. The epiphysis may assume a worm-eaten appearance, which is distinctive of early caries; later this may completely disappear.

Fig. 229.—Radiogram of hand showing injury at the metacarpo-phalangeal joint of index finger.
The base of the phalanx shows, in addition, some rarefaction with expansion of the bone, indicating probable tuberculous disease.

It is important also to be able to distinguish between tuberculous and non-tuberculous disease of bone. In acute and subacute osteomyelitis affecting the neighbourhood of a joint, and particularly in the latter, the tendency is towards the formation of new bone, and the destructive process is not then so manifest. Irregular thickening of the periosteum with the deposition of new bone favours a diagnosis of non-tubercular disease. In some cases a degree of caries sicca preponderates in the process, and then there is not the same tendency to the formation of an abscess. The bone shows rarefaction for a considerable distance up the shaft. An accompanying degree of rarefaction of the bones entering into the joint results from the restriction of movement, and need not necessarily be taken as an indication of the extent of the disease. Ankylosis of the joint may follow the healing of the inflammatory process. Displacements of the bones may result from destruction of the ends, in the hip-joint this being frequently shown as a dislocation upwards.

Figures 231 to 234, from a case of infective osteitis of the neck of the femur, is an instance of non-tuberculous condition of joint involvement which clinically pursued a course similar to a tuberculous condition, except in the early stage which was of an acute inflammatory character resulting in an abscess formation.

In a number of cases where it is desirable to ascertain the extent of the disease, bismuth paste may be injected into a sinus, and when radiographed it may be found to fill up the sinus and demonstrate the diseased area of bone. Stereoscopic plates are very useful in such cases.

The radiographer therefore is frequently asked to X-ray fistulæ connected with bone disease by means of an opaque injection into the sinus. Beck was the first to call attention to the use of a liquid emulsion of bismuth and vaseline. The composition is generally about one of the former to four of the latter. When warmed this runs freely into the sinus, or it may be introduced under pressure from a special syringe.

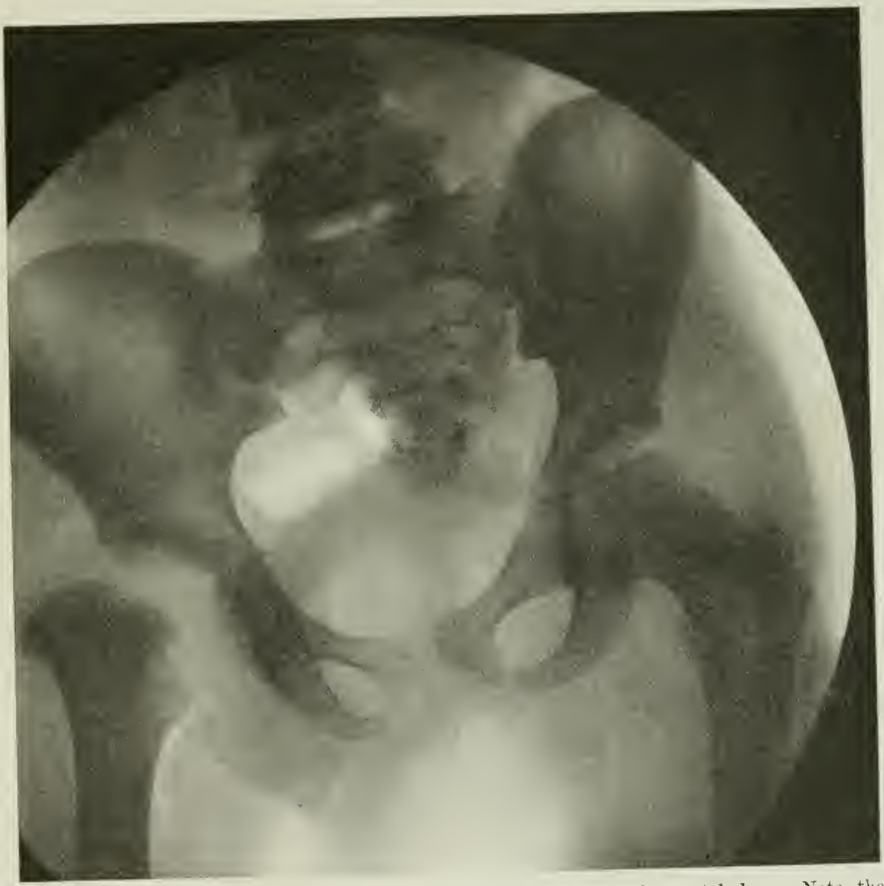


FIG. 230.—Healed tuberculosis of hip-joint, particularly affecting the acetabulum. Note the difference between the two joints and absorption of head and neck, with consequent tilting of the pelvis on the affected side.

Various modifications of this formula have been used. All are more or less unsatisfactory on account of the difficulty of introducing the emulsion and the ease with which it returns from the sinus.

Holtzknecht, Lilienfeld, and Fordes recommend a special rod consisting of the following:

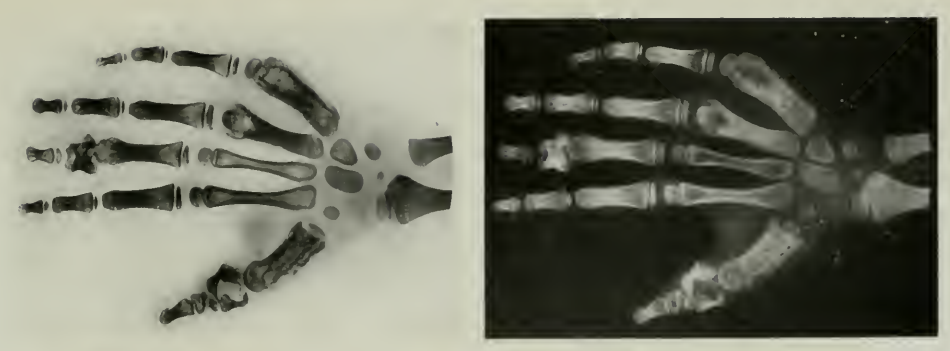
Zirkonoxyd (kontrastin).
Butyri Cacao.
Chini Adeps Lanae.
Xeroform, 5 per cent.

FIG. 231.—Radiogram of a case of infective osteitis of the neck of the femur. (Infective organism, *Staphylococcus Albus.*)

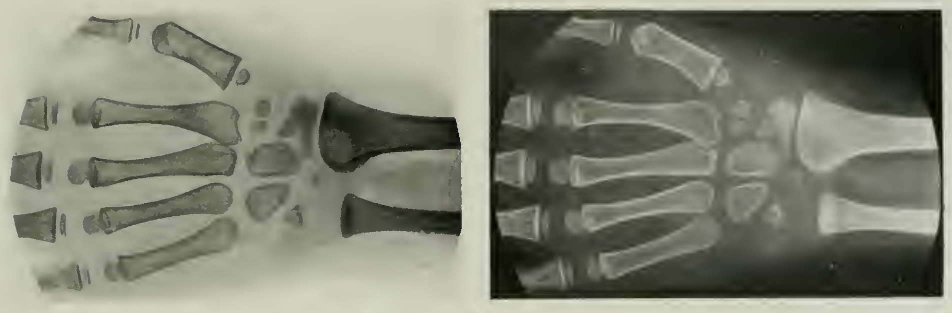
The only evidence of disease is the rarefaction of neck and adjacent epiphyseal line.

FIG. 232.—View of the affected hip taken with an extension tube. This shows more detail of the bone.

FIG. 233.—The same hip taken about two months later. Showing slight displacement of the head upwards.



a



b

c

d

PLATE XLII.—TUBERCULOSIS OF BONES AND JOINTS.

a, Tubercular disease of bones of hand, characterised by new bone formation affecting metacarpal bones and phalanges.

b, Tubercular disease at end of radius, localised abscess. (Radiograph by Dr. R. W. A. Salmond.)

c, Tubercular dactylitis affecting 2nd and 3rd metacarpal bones.

d, Tubercular disease at upper end of humerus (caries sicca). (Radiograph by Dr. R. W. A. Salmond.)

a

b

c

PLATE XLIII.—CHRONIC ARTHRITIC CHANGES AT THE KNEE-JOINT.

a, Rheumatoid changes in knee-joint, with large bony deposit in front of femur.
b, Chronic rheumatoid changes in knee-joint ; loose bodies have formed inside the synovial membrane.
c, Knee-joint, showing extensive changes in patella, probably the result of traumatism.

The rods are 8 mm. long and have a width of 2 mm. They can be made easily, and carbonate of bismuth may be substituted for the kontrastin. Cocoa butter makes a bad mixture with existing pus, consequently it is better to have manufactured kontrastin gelatine rods in which the fatty vehicle is replaced by an aqueous one.

The rods are slowly inserted into the sinus one after the other until the whole length of the sinus is filled, and they are said to penetrate through the smallest channels.

Bismuth subnitrate should never be used for the purpose of filling a sinus, as, if it is retained for any length of time, the presence of impurities may give rise to poisoning.

Fig. 234.—The same case still later, showing disorganisation of the head, displacement upwards of neck, and erosion of acetabulum.

(A still later radiogram showed the arrest of the disease, and distinct evidence of healing process in the bone.)

Tuberculosis may be met with in practically any of the joints of the body, those most frequently affected being the hip, the knee, the elbow, the wrist, the ankle, and the shoulder. The appearances are characteristic. The spine is frequently the seat of a tuberculous caries which ends in abscess formation. In many instances the presence of an abscess can readily be shown by radiographic examination. In a later stage a considerable degree of deformity occurs. The early stages of a tuberculous inflammation of bone, particularly when the spine is affected, is difficult to distinguish from a tumour involving the spine. A consideration of the history and temperature chart will help to clear up the diagnosis. The tumour shadow is usually more irregular, and generally involves the circumference of the bone, while an abscess may be more localised at one part. In doubtful cases an exploratory operation is to be recommended. Simple inflammatory changes in a joint are commonly the result of traumatism. An acute attack quickly subsides and recovery takes place, but it must be borne in mind that a simple injury may end in chronic inflammation, which may later become the seat of tuberculous invasion. In joints traumatism may lead to minute changes in bone and cartilage which, though not definite enough to be recognised as actual fractures, may yet be quite as serious in their after effects. The ligaments may be torn ; this may occur particularly in the knee-joint, when the crucial ligaments are torn. There may even be a fracture of the spine of the tibia. These minute changes should be carefully looked for in all cases of joint injury.

Fig. 235.—Arthritis following injury of knee-joint. Lateral view.

There is a breach in the continuity of the articular surface of the femur. The articular surface of the patella shows slight irregularity. The interarticular space between the femur, head of the tibia, and the patellar ligament is occupied by chronic inflammatory products indicated by a mottled appearance on the print. There is a sesamoid bone in a tendon on the posterior aspect of the joint.

In this print the structure of the bones entering into the knee-joint, and the soft parts, are very well shown. This quality of negative should always be obtained, if possible, when examining joints, for it gives a good definition in all the parts.

Atrophy of Bone may be found in the region of a joint, the result of disease following upon tuberculosis or other inflammatory process.

Chronic Articular Rheumatism

This affects several of the large joints, especially the knee and shoulder. The hip-joint is also affected. Radiographically, the joints may present very little change and show practically no rarefaction. In very chronic cases there may be some irregularity of outline of the articular surfaces, indicating partial absorption of the cartilage.

Chronic Articular Gout

The radiographic appearance of the joints may not show much change, except that the articular surfaces may be unusually close together, and lack the rounded appearance they possess when covered with sound cartilage. Deposits of uric acid are occasionally clearly seen in the radiograph, forming a mass denser than the soft parts but not nearly so dense as the bone itself. Fringes of the synovial membrane may become detached and form loose bodies in the joint.

Loose Bodies in Joints

These are occasionally met with. The following description, which gives the most usual varieties, will be found useful when a consideration of these bodies is called for :

1. Synovial fringes in which proliferation of cartilage cells has occurred, leading to the formation of a nodular mass, which is at first pedunculated, and is then cast off into the cavity of the joint by rupture of the pedicle. These bodies are usually composed mainly of hyaline cartilage, with bony material in the centre of the larger ones. They may become ossified throughout. They vary in size from about $\frac{1}{4}$-inch diameter up to 1 inch ; the larger ones are usually longer than they are broad. There may be only one loose body in the joint, or there may be several hundreds. It is not uncommon to find one body quite loose, and one or more still attached to the synovial membrane of the same joint.

2. Osteophytic outgrowths from the edge of the articular cartilage may become detached, and so form a loose body in the joint. These bodies are irregular in shape, and usually consist of a layer of cartilage covering an osseous centre.

Varieties 1 and 2 usually occur in cases of osteoarthritis.

3. A portion of articular cartilage with a thin layer of bone may become separated from the femoral condyle, and form a loose body in the joint cavity. This occurs probably as a result of injury.

4. A blood-clot in the joint may become gradually smaller and firmer, and so form a loose body. This occurs as a result of injury.

5. A portion of the synovial membrane may become thickened and indurated as a result of injury. This is nipped by the articular surfaces during the movements of the joint, and finally, as a result of the rupture of the pedicle, the body becomes loose.

6. In tuberculous disease of a joint one or several loose bodies may be found. These are composed of tuberculous material in the thickened synovial membrane.

7. Around a foreign body, such as the end of a needle, fibrous tissue may be formed. This and the preceding type of loose body are rare.

8. Partial detachment of a semilunar cartilage gives rise to a body which hangs into the joint. As this is usually still attached to the bone, it cannot be said that it is a true loose body. It, however, gives rise to symptoms of a loose body in the joint.

9. An innocent tumour, such as a lipoma, may form in the synovial membrane, become pedunculated, and so hang into the joint cavity. This is very rare.

10. A metallic body, such as a nail, bullet, or needle, may in rare

instances form a variety of loose body in the joint. These, however, are usually spoken of as "foreign" bodies.

Rheumatoid Arthritis or Rheumatic Gout

Pathologically, in this group the morbid changes occur primarily in the softer structures, the periarticular and synovial tissues undergoing thickening, with hypertrophy of the synovial fringes, while ultimately a process of atrophy, involving the constituent elements of the joints, takes place, including the bony and cartilaginous as well as the softer tissues. (Llewellyn Jones.)

This is characterised by marked deformity in a typical case. Radiographically, the articular ends of the bones present the normal degree of translucency, or they may be more translucent, but there are irregular, knob-like projections, some of which appear more transparent. The joints may become ankylosed, and there is then continuous bony structure right through the joint.

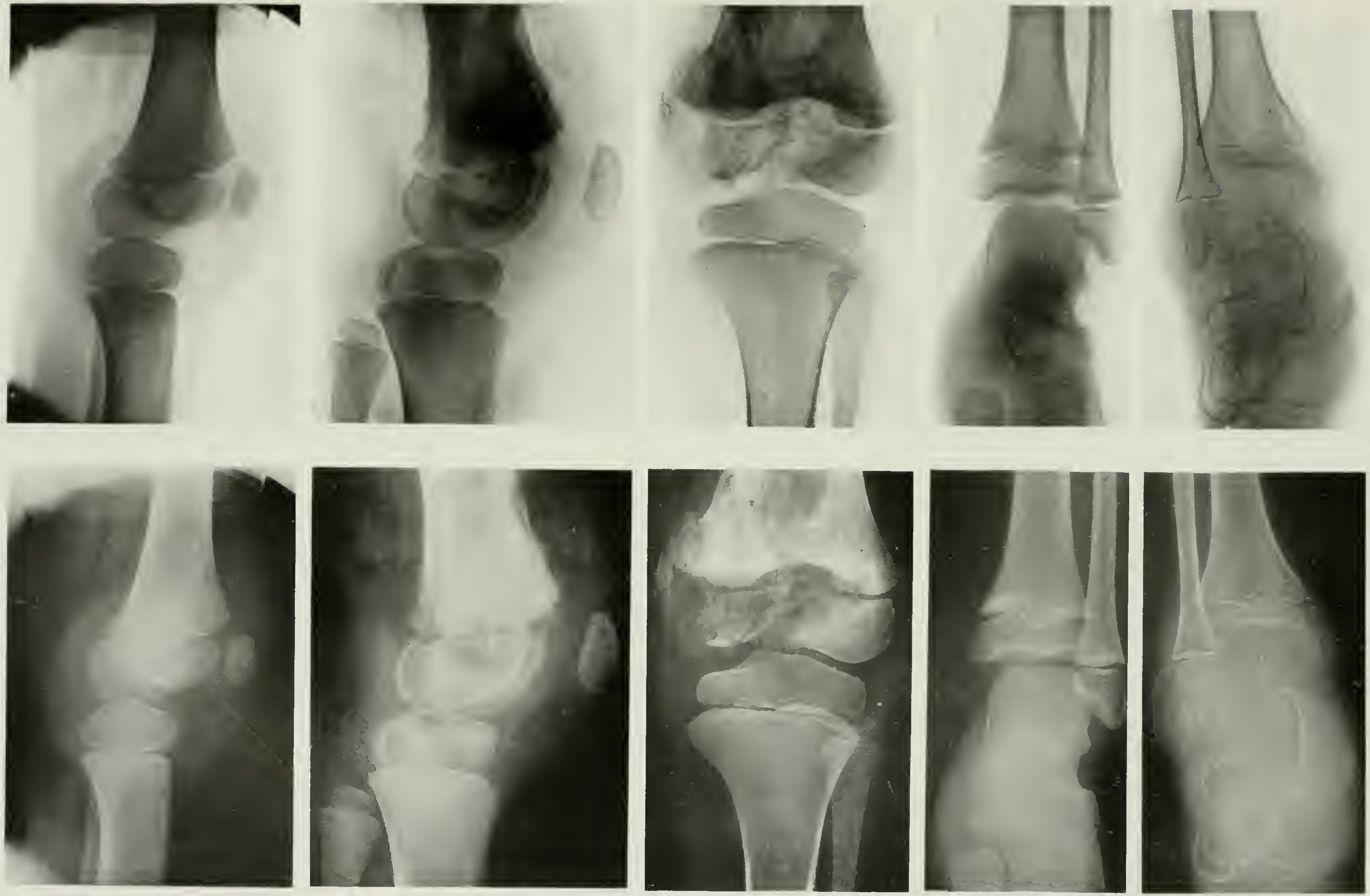
Hypertrophic Arthritis or Osteoarthritis

In osteoarthritis the early changes take place in the bony and cartilaginous structures of the joints, which become enlarged or hypertrophied, with the formation of *osteophytic outgrowths*, contrasting sharply

Fig. 236.—A case of chronic arthritis, probably gonorrhœal, showing a marked degree of ankylosis between the patella and the articular surface of the femur.

with the atrophic process seen in rheumatoid arthritis, in which, if new bone formation occur, it takes place secondarily and is not great in amount.

This is a condition described separately, but it is probably a variety



a *b* *c* *d* *e*

PLATE XLIV.—TUBERCULOSIS OF BONES AND JOINTS.

a

b

c

d

PLATE XLV.—DISEASES AND CURVATURE OF THE SPINE.

a, Caries of cervical vertebrae, lateral view.
b, Curvature of upper dorsal spine (scoliosis).
c, Curvature of spine, involving lower dorsal and lumbar vertebrae.
d, Caries of lumbar vertebrae and sacrum.

of the preceding types, characterised by a tendency to the formation of new tissue between bone and articular cartilage, which becomes calcified. There may be marked disorganisation of the bones.

Spondylitis Deformans.—Osteoarthritis affecting the spinal column. The pathological changes may invade the whole or only a portion of the spinal column. It may be confined to one segment only. In some cases the bony and articular surfaces are more particularly affected, while in others the ligaments and capsular structures are more involved. All stages of the condition may be met with, and should, on radiographic examination, be distinguished from a number of other conditions.

Gonorrhœal Arthritis may attack one or many joints, the knee, ankle, and wrist being the most frequently involved. Two types are recognised. (1) Affecting mainly the synovial membrane, the effusion being chiefly intra-articular, when the appearances are those of a simple arthritis. (2) Affecting chiefly the periarticular structures of the joint involved. There is little effusion into the joint but a good deal around it.

The progress of the arthritis is tedious, displacements readily occur; the effusion into and around the joint is seropurulent and flaky in character. Ankylosis is a frequent result, with a more or less marked disorganisation of the joint structures. Radiographically the condition may be recognised in its later stages by the ankylosis and partial disorganisation of the joint. See Fig. 236.

Charcot's Disease of Joints (Neuropathic Arthritis)

This is characterised by marked enlargement of the joint. The cartilages are eroded, and osseous deposits occur in the ligaments, with irregular outgrowths of bone around the joint.

This condition is generally met with in the course of locomotor ataxy. The most common form met with follows a slight injury, and is characterised by a rapid, painless distension of the joint. These attacks may recur, and after each the joint becomes more crippled, the ligaments become stretched, new bone forms, and the articular surfaces become eroded. The osseous masses may become fused together, ankylosis resulting. Osteophytes are frequently seen in the joint and around it. Partial dislocation may ensue. The condition is readily recognised when radiograms are taken.

In the later stages a differential diagnosis has to be made from osteoarthritis.

DIFFERENTIAL X-RAY DIAGNOSIS IN DISEASES OF BONES AND JOINTS

It is important to be able to suggest, if only tentatively, a differential diagnosis in morbid conditions of bone, and, when the disease is near a joint, also regarding the condition of the joint. The tumours of bone most likely to complicate a diagnosis are (1) sarcoma, (2) cancer. The latter is generally accompanied by a primary lesion elsewhere, but the former frequently arises primarily in the periosteum (periosteal sarcoma) or in the substance of the bone (endosteal sarcoma).

It is necessary to consider the appearances presented by tumours of bone when dealing with what appears to be an inflammatory condition. The subject will be dealt with more fully later. Tumour of bone may be complicated by superadded inflammatory changes which lead to still greater difficulties in diagnosis.

Sarcoma usually attacks the shaft of the bone, and produces changes similar to those caused by certain degrees of osteomyelitis, differing, however, in that the latter show a more pronounced degree of periosteal reaction, as indicated by the deposition of new bone and the tendency to formation of sequestra. In medullary sarcoma certain areas of increased density appear which resemble spiculæ or islands of osseous material, and show actual absorption of the bone, with very few or no normal portions of bone remaining about this point. In osteomyelitis, in addition to the more definite thickening of the periosteal shadow, there is a more definite formation of new bone about the necrosed area.

Appearance of Joints in Tuberculosis

When examining joints for evidence of tuberculosis the following changes should be looked for. They are met with in the course of many examinations of these cases. The earliest changes are naturally the most difficult to recognise.

(1) Marked porosity of the bones forming the affected joint, resulting in a readier passage of the rays, and a consequent increase in the effect upon the plate, appearing on the negative as darker areas.

(2) Actual loss of substance in the head, *e.g.* of the femur.

(3) Actual loss of substance in the hollow bone, *e.g.* the acetabulum, glenoid, etc.

(4) Extreme atrophy of the shaft of the bone. This is most marked when the condition has existed for a lengthy period of time.

(5) Abscess formation, characterised by an increase of the normal shadow of soft parts around the joint, accentuation and bulging of the joint outline.

(6) Necrosis of portions of the bones, with formation of sequestra, readily recognised in the radiograph.

(7) Arrested development of epiphysis, and changes at epiphyseal line, with later marked shortening of the long bone.

(8) Displacement of bones, particularly at hip-joint. Where the head or neck of the femur is displaced upwards this indicates that there is a marked change in the acetabulum.

(9) Ankylosis of the bones forming the joint. This condition is frequently an end result of tuberculosis of joints.

Tubercular Dactylitis

This is characterised by enlargement of the affected bones, deformity, and destruction of bone tissue. Enlargement of the bone is often accompanied by rearrangement of the structure of the bone. Variations in density give the appearance of cysts in bone, the bone surrounding a rarefied area becoming sclerosed in parts; hence the cystic appearance. The chief conditions met with in the differential diagnosis are: (1) Cystic disease of bone; (2) chrondromata, commencing in the shaft of a long bone; (3) tumours of bone, *i.e.* malignant disease; (4) syphilitic dactylitis.

Syphilis of Bone

(1) Periosteal proliferation leads to considerable thickening, irregular in character.

(2) Areas of increased rarefaction due to marked absorption of the lime salts, with an effort towards new bone formation.

(3) Periostitis leads to many layers of new bone being laid down along the whole length of the bone. Generally multiple, it therefore affects many of the long bones.

In other cases the thickening may be localised, causing areas of dense new bone formation. The diagnosis has to be made on the clinical findings, the history and the result of well-known tests for syphilis and tubercle, and on the radiographic appearances.

Syphilitic Dactylitis

This is characterised by periosteal overgrowth, with little or no apparent disturbance of the bone, the appearance presented by this condition affording a fairly reliable diagnostic point in favour of syphilis.

Chronic Infective Osteomyelitis

(1) General infiltration causes a deeper shadow about the bone and joint when the disease appears in the vicinity of the latter.

(2) Periosteal infiltration and overgrowth lead to marked increase of the adjacent bone, and this sclerosed bone appears to be much denser than normal bone, and the shadow is greatly increased in area.

Acute Osteomyelitis

The earliest X-ray appearance of an osteomyelitis, which may run through all the stages of the disease in a few weeks, may be an area of rarefaction in the diaphysis close to the epiphyseal line, and later in some cases extending into and involving the epiphysis. This is followed by periosteal thickening, necrosis of bone, evidenced by areas of varying density, indicating sequestra. The disease may become localised, when radiographically it is shown by an area of lighter shading surrounded by a periphery of denser bone. The condition may arise near the epiphyseal line. Abscess of bone may be the result of the inflammatory process, a typical instance being the well-known abscess in the upper end of the tibia or lower end of the femur.

In the hip-joint a mixed infective process may give rise to appearances which have to be differentiated from tuberculous disease. Though the appearances may indicate a preponderance of evidence in favour of one or other of these diseases, it is not always possible to distinguish between them. A condition where there is a tendency to proliferation of periosteum, thickening of bone and osteophytic outgrowth is more in favour of a non-tuberculous condition. It must not be overlooked, however, that a condition which commenced as a tuberculous one may become the seat of a mixed infection or *vice versa*. An infective disease of bone may, so far as actual damage is concerned, be similar to tuberculous disease. Figures 231 to 234 show a number of radiograms from a case of this kind, where the earliest manifestation of disease was seen in the neck, below the epiphyseal line. The clinical course and result of treatment was precisely similar to that of a tuberculous infection of the joint. Marked evidence of bone disease in the vicinity of, but not involving, a joint, is rather an indication for a diagnosis of a non-tuberculous origin for the disease. A typical case may occur in the upper end of the femur, when an area of lessened shadow (*i.e.* a condition which allows of the readier passage of the rays through the bone substance) is due to a destructive process in the bone, with absorption of the bony salts. This is accompanied by a greatly thickened periosteum. The bone, therefore, appears on examination to be denser in the surrounding areas, in contradistinction to the general rarefaction which is so frequently seen in chronic cases of tuberculosis.

The typical X-ray picture of a case of chronic osteomyelitis in an

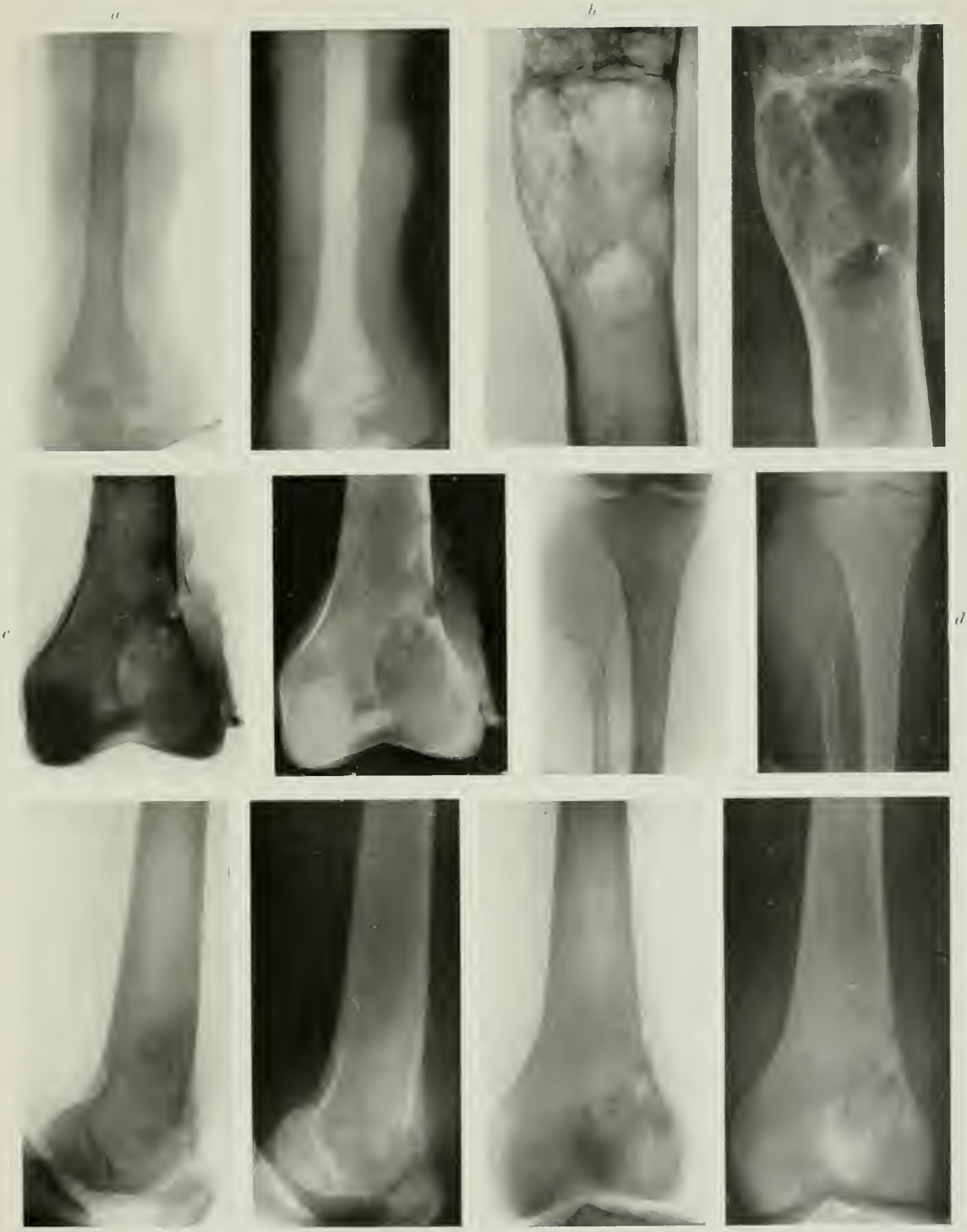


PLATE XLVI.—Tumours of Bone.

a, Periosteal sarcoma of shaft of humerus. Plate L. fig. *a*, shows recurrence in lung two years after amputation of arm. *b*, Myeloid sarcoma of shaft of humerus confirmed by microscopic examination. There have been several fractures at the seat of growth.

c, Sarcoma of lower end of femur (after removal). *d*, Sarcoma of head of fibula. (Radiograph by Dr. Reid.)

e, Lateral view of *c*, from living subject. *f*, Antero-posterior view of *c*.

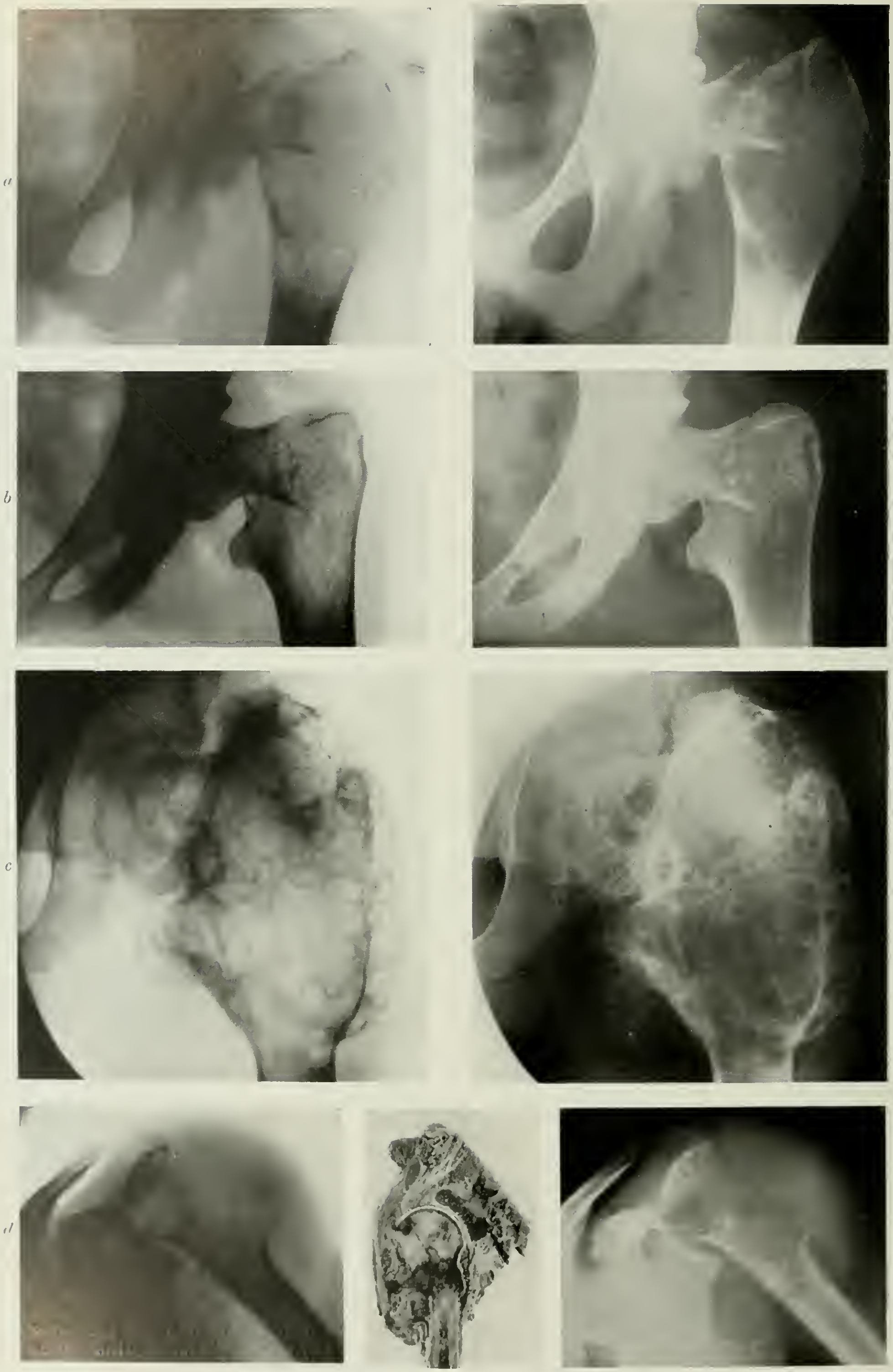


PLATE XLVII.—TUMOURS OF BONE.

a. Secondary sarcoma affecting upper end of femur, fracture through neck. The primary lesion was a periosteal sarcoma of humerus.

b, Same case at an earlier stage. (Radiograph by Dr. N. S. Finzi.)

c, Sarcoma of upper end of femur. The diagnosis in this case is doubtful; it is most probably a myeloid sarcoma of very slow growth.

d. Sarcoma of upper end of humerus (inset is a photograph of the joint after removal). The humerus has been fractured probably as a result of manipulation, at or after the operation.

advanced condition, when the whole of the shaft of a bone has become involved, shows :

(1) Areas of suppuration indicated by patches of varying density, rarefaction of bone, and small collections of debris and pus.

(2) Newly formed periosteal bone, shown by the deposition of successive layers of bone outside the shadows of the original bone or what remains of it.

(3) Necrosis of the cortical bone, indicated by irregular patches of denser shadow, with a well-defined periphery, beyond this being lighter shadows, where the living bone still remains.

Generally these conditions are confined to the shaft of the bone involved, the epiphyses and joints escaping. The earliest X-ray manifestation is shown by a slight increase in the periosteal shadow at one or more spots, a definite swelling of the soft parts, and possibly abscess formation.

Acute Infective Periostitis

The diagnosis by X-rays of an early infection of the periosteum is attained by noting changes, such as thickening and bulging of the periosteum. The outline of the periosteum in normal bone is sharply defined, while in acute inflammatory conditions there is a general haziness of its outline in the affected part, or it may be broken and irregular, exposing the cortex of the bone.

The formation of an abscess is shown by an increased depth of shadow in the neighbouring soft parts. In less acute cases this swelling may be due to inflammatory changes commencing in the periosteum.

Tumours of Bone

The simple forms of tumour are often diagnosed with ease, but the malignant tumours are frequently the subject of great doubt, both clinically and radiographically. The latter method of examination is often called upon, to decide, if possible, the nature of a doubtful swelling. In all such cases great care must be exercised, and all methods of examination should be employed. To make a positive diagnosis on the radiographic appearance alone is often misleading. The most malignant type of sarcoma, for instance, is, in the early stages at least, indistinguishable from a simple inflammatory process. Later, more decided features may be made out, but it must be insisted upon that radiographically it is often impossible to decide. The clinical history, the radiographic evidence, and in most of the early cases the examination of a fresh section of the tumour at the time of operation should all be employed. The latter method puts the nature of the case beyond all doubt, and decides at once the extent of the operation.

The clinical and radiographical features of cases of tumour will be dealt with later, but, in passing, it may be observed that a knowledge of the macroscopic and microscopic appearances of tumours will aid the radiographer to grasp points in the progress of a case, which will often help to decide his opinion in a particular instance.

Sarcoma is the most important primary tumour of bone, and almost any form of this may occur. Endosteal, or central sarcoma generally commences in the medullary cavity or cancellous tissue, and results in the so-called "expansion" of bone, which consists of an absorption of bone from within, whilst at the same time new osseous tissue is being deposited from the under surface of the periosteum. The radiographic appearances will correspond with the pathological changes. Expansion of the bone with debris in the centre or sarcomatous new tissue, will be shown in the plate. The new bone forming from the periosteum is deposited in more or less definite layers. When considerable expansion of bone occurs, it can readily be distinguished from inflammatory change processes, or cysts of bone, by the somewhat sharp nature of the expansion. The shaft above and below the growth is normal, and suddenly expands at the site of the tumour.

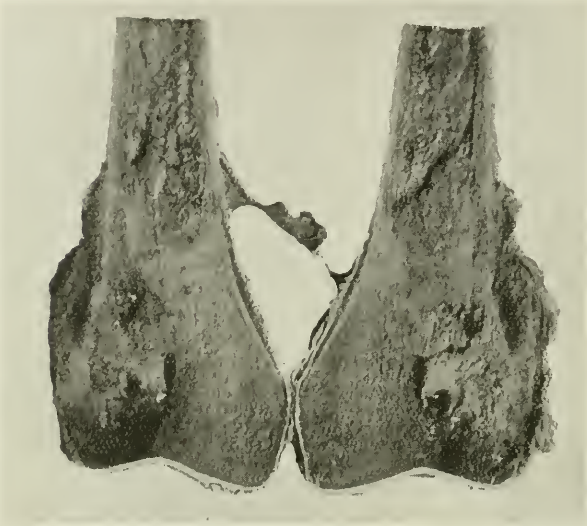


FIG. 237.—Sarcoma of lower end of femur.
The bone has been sawn longitudinally in order to show the tumour in its interior. The appearance of this tumour in the amputated limb and in the living subject are shown in Plate XLVI., Figs. *c*, *e*, and *f*.

The growth usually commences at the end of a long bone. It seldom encroaches on the articular cartilage, so that the joint escapes, although it may be distended with fluid. Dr. Emery, of King's College Hospital, has been good enough to report on the tumour shown in Fig. 238. "It consists of a cellular matrix, composed for the most part of large, round, or oval cells, having large nuclei, sometimes multiple. There are also a few myeloplaxes. This part of the tumour is sarcomatous in type. Set in this tissue are numerous masses of cartilage, fairly well formed, but with tumour cells (like those of the matrix) instead of ordinary cartilage cells. The tumour is a chondro-sarcoma."

Spontaneous fracture is a not uncommon complication, and owing to the expansion of the bony framework, "egg-shell crackling" may be met with. Later, the growth may expand beyond the bony limits of the growth, and secondary deposits occur, the situations in which these are found depending upon the type and position of the primary tumour. The lungs and mediastinum are frequently the seat of secondary growths.

The periosteal type of sarcoma is not at all easy to distinguish. It may appear as a decided shadow of about the density of the soft parts, arising from the surface of the bone. It involves the soft structures, extending into them in some instances. The periosteum may show thickening, which will be revealed radiographically.

FIG. 238.—Chondro-sarcoma of lower end of tibia.

FIG. 239.—Sarcoma at upper end of humerus. This is a form of periosteal sarcoma which rapidly involved the soft parts. Radiographically, the humerus showed very faint irregularity at the periphery with thickening of the bone.

Myeloid sarcoma in its least malignant form may simulate a cyst of the bone. It is of slow growth, and occurs at the ends of long bones. Spontaneous fracture may occur in this as in cystic disease.

Hydatid cyst may also be met with. It is more chronic in its progress, and shows a well-defined, fairly regular outline.

FIG. 240.—Tumour of clavicle (Radiograph by Dr. R. W. A. Salmond). Sarcoma of acromial end of clavicle. This has the appearance of a cystic condition of the bone. It developed rapidly.

Carcinoma of Bone.—This is usually secondary to a primary focus elsewhere—in the breast, genito-urinary tract, etc. It is generally a late secondary manifestation, the bones most frequently affected being the sternum, ribs, and spine. The disease may also invade a large joint, or the shafts of the long bones may become involved. The sacrum or iliac bones may also be invaded. The presence of these secondary deposits is shown radiographically by rounded irregular shadows of varying density, generally lighter than the normal bone. In other cases the disease takes the form of cario-necrosis, when cavities filled with necrosed tissue are produced, and appear on the screen or plate as well-marked areas. When examined on a radiograph these areas are darker, on the print they appear as lighter shadows.

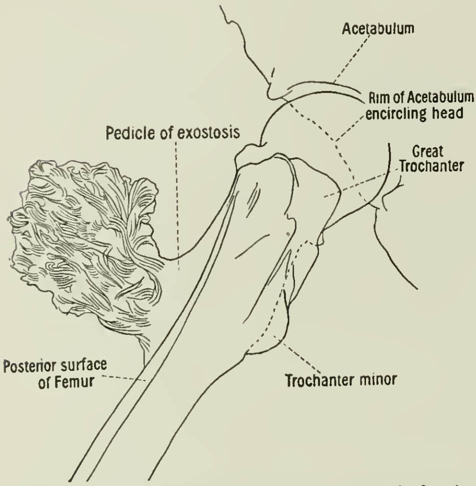


Fig. 241.—Diagram to illustrate the anatomical points in Fig. 242. The femur has been radiographed in an approximately lateral position.

Fig. 242.—Exostosis of the upper end of femur, attached to the posterior surface.

Exostoses.—These show as projections, sometimes of normal bone tissue, and sometimes of rarefied or unusually dense bone; the situations in which they are met with are numerous, as in the ends of the long bones, bones of the feet, the pubis, etc.

Chondromata. — These may occur in any bone, but particularly in the long bones, and also in the bones of the fingers and toes. The tumour may expand the bone. If ossification should occur in the tumour it may be difficult to distinguish this form from osteoma or osteo-sarcoma of bone.

Differential Diagnosis of Tumours of Bone

A brief summary of the commoner forms of tumour of bone and of the points which are most useful in diagnosis is necessary. It is also well to remember that there are no positively definite signs of any particular tumour.

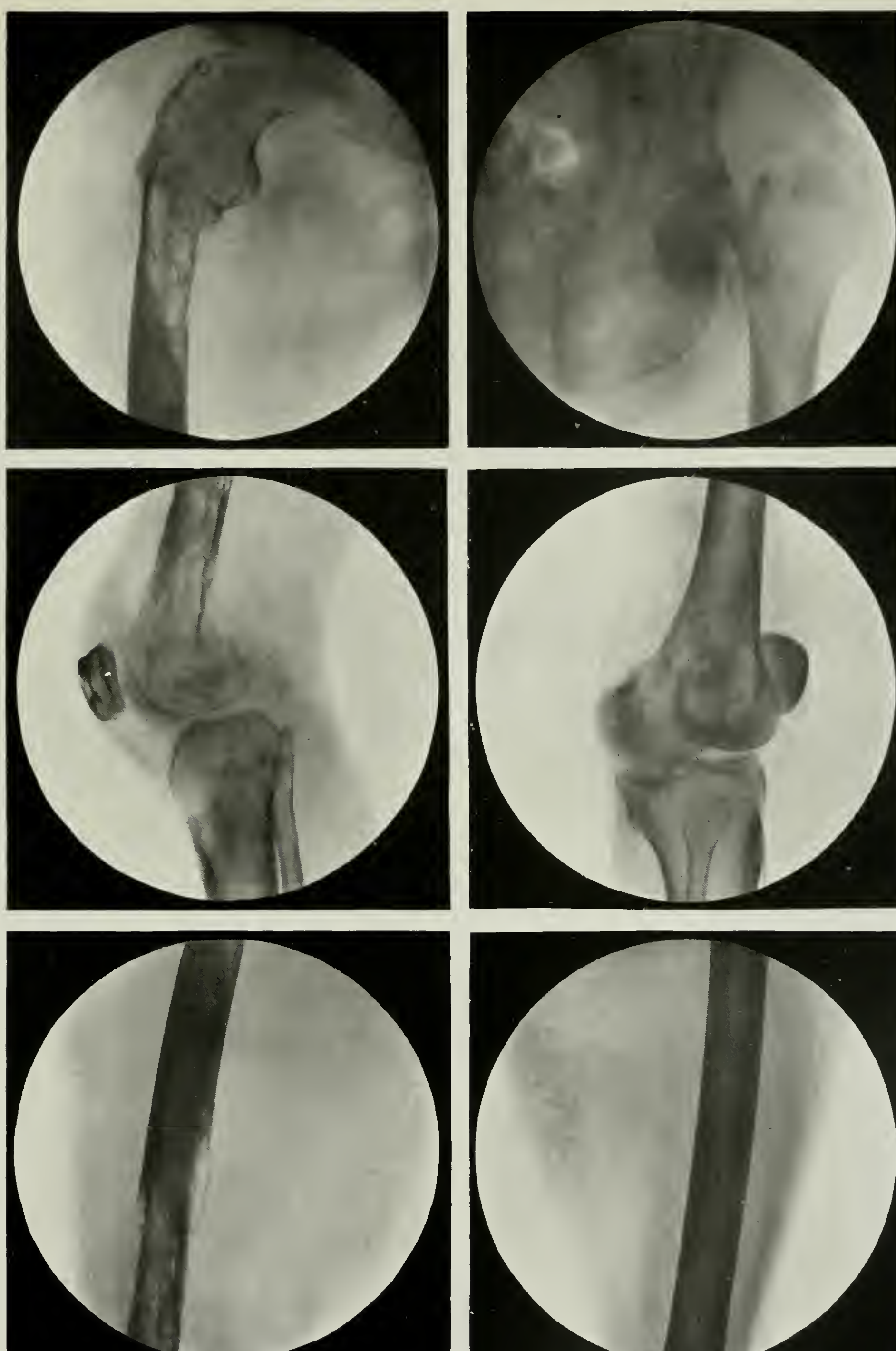


PLATE XLVIII.—SECONDARY CARCINOMA OF BONE.

Secondary changes in bones from a case of carcinoma of the breast.

a, Involvement of upper end of femur with absorption of the head and displacement of the shaft upwards.

b, Left hip joint, showing fracture through the neck.

c, Right knee-joint, showing advanced changes in the bones.

d, Left knee-joint, shows an earlier stage where the bone is just commencing to be involved.

e, Advanced changes in shaft of right femur; absorption of portions of bone, with periosteal new bone formation.

f, Left femur, showing early rarefaction of upper portion.

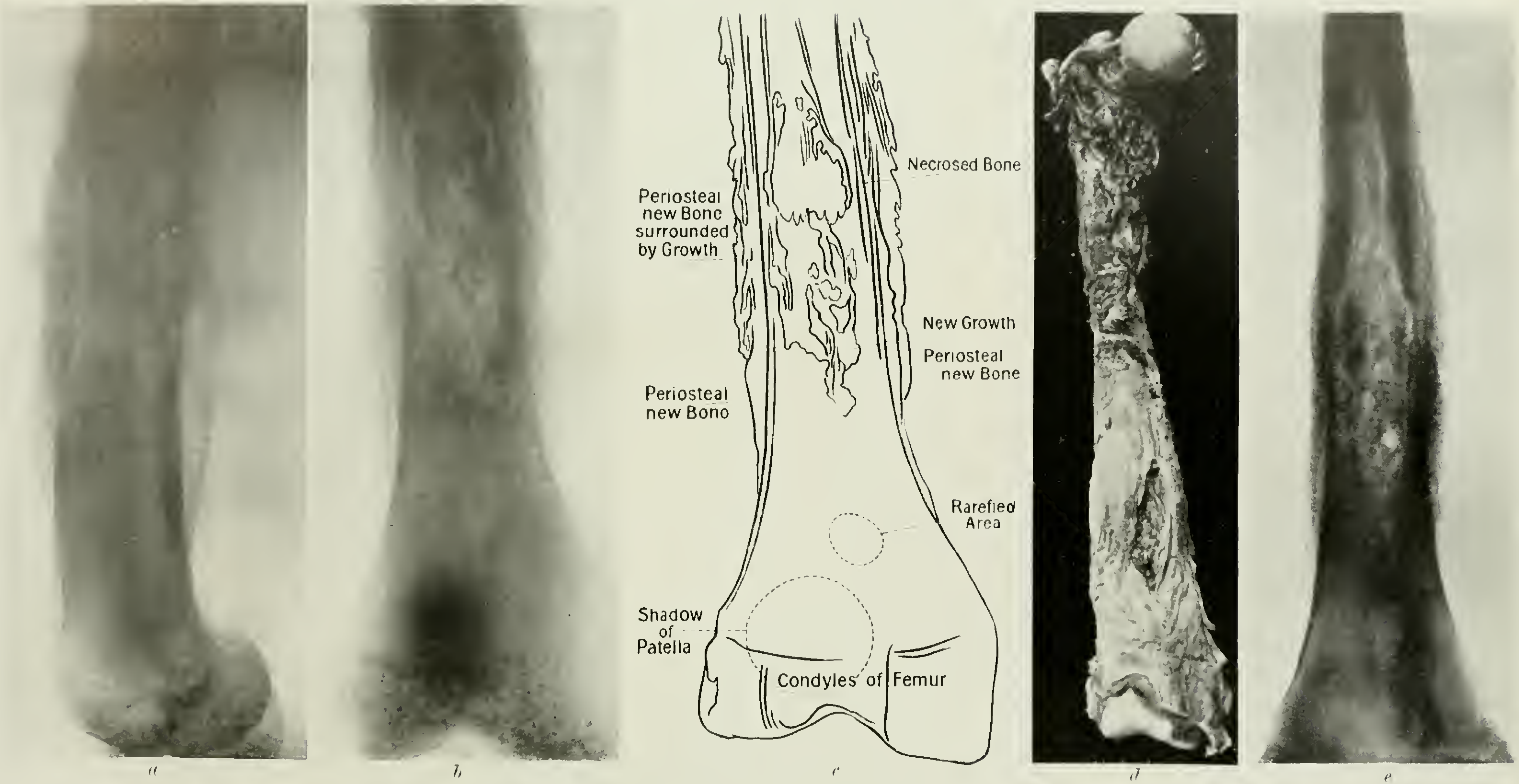


PLATE XLIX.—Sarcoma of the Shaft of the Femur.

a and *b*, Lateral and antero-posterior view in the living subject.
d, Photograph of the bone after removal.
e, Radiogram of the bone.
c, Explanatory diagram.

This case was a difficult one to diagnose as it presented radiographic evidence which might have been due to new growth or inflammatory bone disease.

Clinical data and radiographic records should be taken together if the examination is expected to be of value.

The appearance of a shadow of doubtful nature in one of the long bones raises most important questions of diagnosis. The benign cyst has recently been shown to be a comparatively common tumour of bone. The term benign is used in relation to the degree of malignancy and growth rather than as a pathological classification. Many of these so-called benign growths are myeloid sarcomata, which are peculiarly slow in the rate of growth. The tumours most likely to lead to difficulty in diagnosis are those which are found in the interior of the shaft of a long bone, or at its epiphyseal ends, and which have rarefied or replaced the osseous or medullary tissue, with or without expanding the bone, and which are situated within the osseous tissue of the bone. Such tumours may prove to be (1) central abscess, tuberculous or septic; (2) gumma; (3) hydatid cyst; (4) benign cyst; (5) fibrous osteitis; (6) enchondroma; (7) endothelioma; (8) secondary carcinoma; (9) myeloma; (10) sarcoma.

FIG. 243.—Enchondromata of bones of hand.
The metacarpal bone of the index finger is extensively involved by an expanding growth which is in parts ossified. The first and second phalanges show an earlier stage of the same condition, characterised by rarefaction of the area involved, which has not yet begun to expand. The second phalanx on its ulnar side shows a bud-like projection at the proximal end of the rarefied area.

FIG. 244.—Traumatic myositis ossificans.
Note the unchanged aspect of the bone. The ossification in the muscle bundles is quite distinct from the periosteum.

The points to be considered are: (1) history; (2) physical signs; (3) evidence of disease or tumour in other parts of the body; (4) radiographic appearances, and a correct interpretation of these. The chief of these, so far as our purpose is concerned, is the radiographic appearances, though all should receive attention.

The points of importance radiographically are the site of the tumour in the bone, its density and consistence, whether subdivided by trabeculæ, its outline, whether sharply defined and surrounded by a well-defined shell of bone, whether the bone around is normal or rarefied, presence of deposits of new periosteal bone or sclerosed bone, the presence of a fracture, the evidence of erosion of the bone.

Traumatic Myositis Ossificans.—A condition which arises in the substance of a muscle secondary to trauma. It occurs most frequently in the arm or the thigh. The appearances are characteristic and must not be mistaken for sarcoma arising from the periosteum. Fig. 244 illustrates the typical appearances in this condition.

Central abscess is generally accompanied by symptoms, however slight, namely, pain and loss of power, indicating an inflammatory process, and occasionally by fluctuations in temperature. Radiographically, the cavity is not as a rule strictly central, and the surrounding dense bone is unequal in its thickness. The outline is often indefinite, the cavity is not very clear, and there is an absence of trabeculæ. The bone around is denser, and there is generally a deposit of new bone.

Hydatid Cyst.—This is very rare in this country, though it should always be kept in mind when considering obscure conditions. It shows as a sharply rounded area less dense than bone.

Benign Cyst is a much more common occurrence than was formerly thought. The first sign may be a so-called spontaneous fracture of the bone, this occurring as the result of violence of a mild kind. The appearances are characteristic. The cavity or cavities are situated centrally ; they fill the bone uniformly, the space indicating the cyst being clear and not subdivided by trabeculæ. There is little or no sclerosis of bone, and no periosteal thickening, though this may occur as a result of fracture.

Fibrous Osteitis.—Probably always originates in early life. It is characterised by swelling and deformity, the latter being due to bending of the softened bone. The disease may be localised to one bone, the upper end of the femur being the most frequent site, when the bone is expanded. Skiagrams show expansion of nearly the whole shaft. There are great variations in density, and an appearance of subdivision by trabeculæ. These appearances lead in the diagnosis to confusion between this condition and myeloma.

Secondary Carcinoma.—Radiographically, there may be seen a clear area in the middle of the shaft of a long bone or a rib, giving the appearance of a rarefied patch in the bone, covered by a thin shell of compact bone, and fading gradually up and down the shaft into normal bone. See Plate XXXVIII.

Myeloma.—They are most likely to be confused with benign cyst or with fibrous osteitis. They are generally found at the ends of the bones. Radiographically, the distinguishing features are the expansion of the bone and the subdivision by trabeculæ.

Sarcomata of Bone.—These are periosteal and endosteal. The former are often difficult to distinguish from inflammatory thickening or myositis ossificans traumatica. Periosteal sarcoma usually begins at the periphery of the bone and leads to a degree of thickening which may be mistaken for periostitis or osteitis. In the latter there is generally more marked periosteal reaction, evidenced by a greater formation of new bone about the necrosed area, or there may be areas where the bone has become absorbed. A sarcoma may, however, originate in the muscles or connective tissue, and by pressure lead to changes in the bone which will confuse the diagnosis. In such cases the diagnosis has to be made between chronic inflammatory processes and new growth. It may be that a differential diagnosis is impossible by means of radiography. The tumour, when originating in muscle or connective tissue, may become encapsuled in fibrous tissue, and the bone may not be involved.

Medullary Sarcoma is probably the rarest of the endosteal tumours of bone. The bone is expanded with great rapidity, and the bony shell is often eroded. Erosion seen in a skiagram should always excite suspicion of the true nature of the disease. The appearance in a skiagram of a clearer area, *i.e.* offering less obstruction to the passage of the rays, in the shaft of a bone, expanding the bone unequally, and showing erosion of the bone substance, should lead to the suspicion of sarcoma.

THE X-RAY EXAMINATION OF THE THORAX AND ITS CONTENTS

The complete routine examination of the thorax includes an investigation of the bony walls, the trachea and bronchi, the heart and aorta, the lungs, the mediastinum, and the œsophagus. The bony walls have been dealt with in the chapter on injuries of bones, and the œsophagus in that on the alimentary system. For our present purposes, therefore, the routine examination of the chest consists of a scrutiny of the heart, the lungs, and the mediastinum by the methods of Radioscopy and Radiography.

Radioscopy

Radioscopy, or the examination of a patient with the fluorescent screen, is a method of great value, as a diagnosis can often be made from it alone, to be subsequently confirmed by radiographic exposures. To obtain reliable results it is essential that the technique should be complete.

Technique of Examination.—Several methods are employed :

1. *The Recumbent Position.*—The patient may be placed on the X-ray couch, the tube working from below and the operator manipulating the screen. The position of the tube and of the diaphragm aperture are adjusted to suit the requirements of the case. It is essential to have a good X-ray tube of the proper degree of hardness, and an evenly spread fluorescent screen.

2. *The Upright Position*, with the patient standing in front of the X-ray tube, is undoubtedly the best. For this method, a well-protected screening stand, all the parts of which work with ease and smoothness, is necessary. The particular form of stand varies with the desires of the operator, but in order that good results may be obtained a good stand is essential. A convenient form is illustrated opposite. A few minutes' consideration of the mechanism will familiarise the operator with its movements, and it need not therefore be described. A rectangular diaphragm is better than one of the iris shape, as with the rectangular form it is possible to examine in detail the roots of the lungs in their entirety.

The room should be completely darkened, not even a glimmer of light being permissible when the tube is working. An open fireplace for heating purposes is not advisable, but if such is used, then efficient steps must be taken to exclude light from it during the examination. It is also necessary to enclose completely the X-ray tube and valve tubes in a box or in black cloth, and even the front of the X-ray box must be covered with an opaque cloth, if reliable observations are to be made.

These precautions taken, the operator should allow a few minutes to elapse in the darkened room before the current is allowed to pass through the tube, in order that the retina may become sensitive to the fluorescent appearance of the screen when the tube is working.

It is a good plan to have in the radiographic room one or more ruby lights, then the ordinary preparatory work may be done in the ruby light. It is found that the red light enables the operator and observer readily to see the structures on the fluorescent screen when the X-rays are in action. It is not then necessary to wait in a darkened room before turning on the X-rays.

The Routine Examination.—This should always be carried out in a definite order. The tube should be first centred over the heart, with the diaphragm opened to its widest limit. This enables a view of the whole of the thorax to be obtained. At this stage it is well to compare carefully the two apices, using the diaphragm sufficiently open to allow of an examination of both at once. Then the tube should be carried well down, and the movements of the diaphragm examined for limitations on either side, and the presence of dulness at either base looked for.

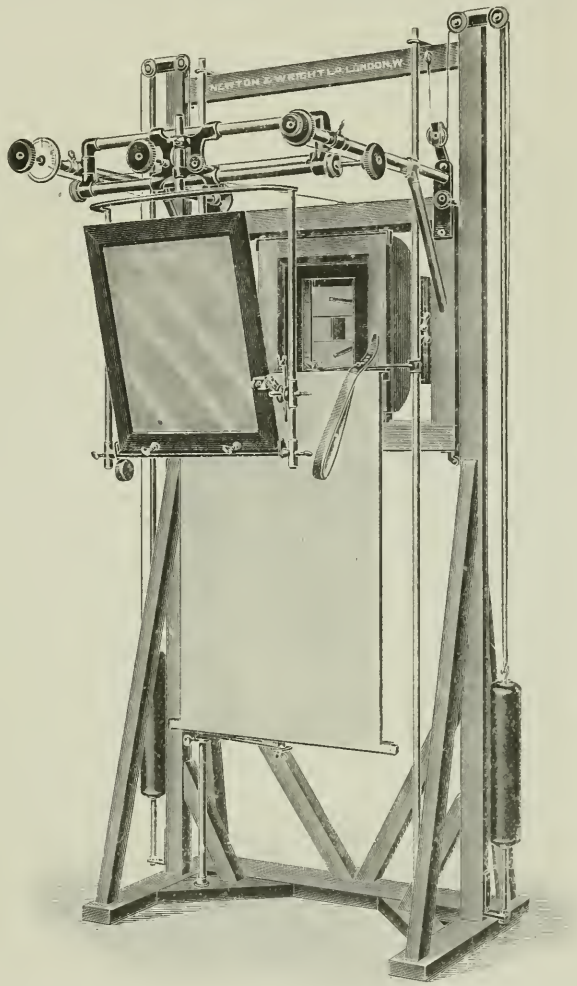


Fig. 245.—Upright screening stand, suitable for taking radiographs of the thorax. (Newton & Wright.) For stereoscopic work a rapid plate-changing device must be added. See Fig. 99, p. 106.

Next the heart and aorta are carefully scrutinised for abnormalities of size, shape, or position, or for the presence of pulsation in abnormal situations.

The tube should then be moved over to the right side of the chest, and the diaphragm of the apparatus closed laterally until a long slit aperture is obtained. This is carefully adjusted over the hilus of the lung for the detection of enlarged or calcareous deposits in the glands. The appearance of the shadows at the root of the lung should be noted. Repeat the observation on the left side.

Great care should be exercised in the examination of the apices of the lungs, both as regards the quantity of current passing through the tube and the observation of the apices themselves. After one apex has been examined a mental note should be made of the degree of the illumination present, and the tube then passed over to the other side. Differences between the two apices should be carefully noted.

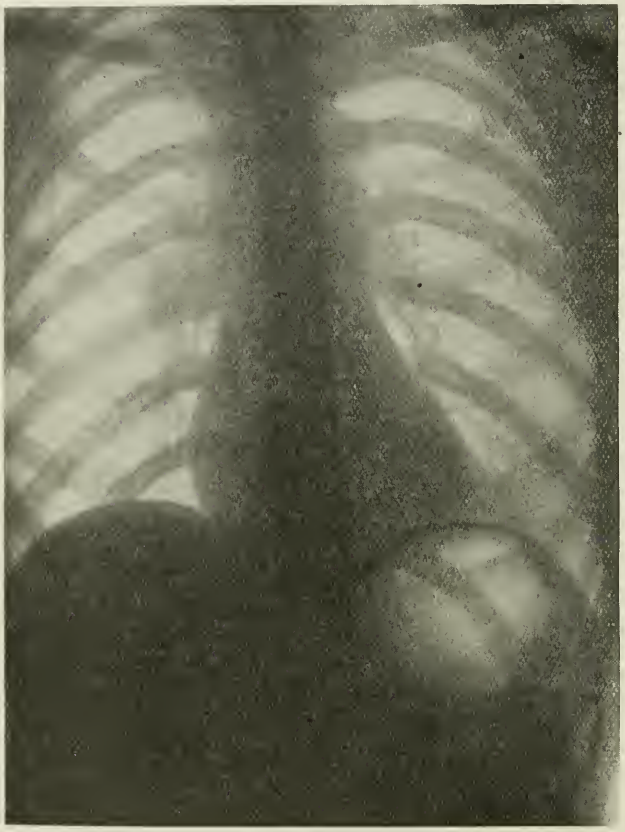


Fig. 246.—Thorax of an adult, showing practically a normal condition except at the root of the right lung where there is a slight increase of shadow. (Exposure $\frac{1}{10}$ sec.)

The current passing through the tube should be regulated by the operator, and this is best done by an adjustable rheostat close to his hand. With a soft tube and a small primary current, very fine detail in the lung substance can be made out. This is most important, for it is often by the examination of this detail that a diagnosis of early tubercular disease may have to be determined.

Diagrams may be made on the lead glass in front of the fluorescent screen of any particularly striking departure from the normal, alterations in the diaphragm can be sketched in, and the amplitude of movement on inspiration and expiration noted. A permanent record of the amplitude of respiratory movements of the diaphragm can be obtained by getting the patient to inhale fully and hold the breath. An exposure is made. Then the patient exhales forcibly, and holds the breath while another exposure is made. The two shadows on one plate show the degree of diaphragmatic excursion. All observations of this kind should be immediately transferred to paper on completion of the examination, and entered in the notes of the case.

These observations are of the greatest value in all cases ; but if they are to be useful a note must be made at once, otherwise the personal element will enter largely into the case. Even under the most favourable conditions this factor must be considered, since it is the great objection to all screen examinations. In no other region of the body are we so absolutely dependent upon screen examination of a patient. The trained eye of the observer may detect changes in movement in lungs or heart which it is impossible to record upon a plate. But radiographs which are taken instantaneously are of great value as confirmatory evidence of changes in the organs, and should always be taken to complete the examination. The importance of having a thoroughly reliable fluorescent screen must be borne in mind. It is also essential that the screen be smooth on the surface, and kept scrupulously clean. The lead glass protection should also be kept well polished, for even a trace of dirt or pencil mark on its surface may lead to trouble, the importance of this point being readily understood where fine detail is being dealt with.

Fig. 247.—Normal lower cervical and upper dorsal vertebræ. The apical part of both lungs is also well shown.

It is also of importance to have the patient perfectly still, especially when radiography is employed, since the slightest movement during the exposure may ruin the value of a plate. The screening stand should be connected to earth by a wire, in order to avoid giving the patient a shock from the electrical discharges which are given off from the tube and metal fittings when the former gets hard.

Radiography

In radiography of the lungs for diagnostic purposes it is necessary to use a soft tube in order to obtain the best results. It is detail in lungs and not in bone that we look for. A soft tube of about 3-4 inch spark-gap will allow a large quantity of current to pass through it, and will give very good detail in the soft parts.

Time exposures of any length are of no great value for diagnosis ; if we are to get plates which will to any extent reproduce what we have seen on the screen, the exposure must be exceedingly short ; in fact, the shortest obtainable is the best. With a powerful modern installation the exposure may be cut down to $\frac{1}{100}$ of a second. The resulting picture is of great value, because everything is absolutely sharp, the heart being represented in outline by the sharpest possible line. The diaphragm is also sharp, and may be caught in a stage of contraction. This is well shown in a print from a case of early phthisis (see Plate LIII., Fig. *b*).

The hilus of the lung and the shadows in it are also well shown. The branching of the bronchi and larger vessels can be followed to the periphery, and if the tube has been in the proper condition a faint mottling all over the surface represents the lung substance.

From a comparison of such pictures obtained from normal subjects it is quite easy to detect changes which occur in diseased conditions, especially in the very early stages of tuberculosis of the lung. Even with the most up-to-date apparatus it is still necessary to use an intensifying screen, if the exposure is to be of the shortest possible duration. With a screen of this kind quite good pictures may be obtained with much less powerful installations, but their diagnostic value in very early cases is not nearly so great.

The important point in these very rapid exposures is that they reproduce one phase of what one sees when a screen examination of the chest is made, with all the movements of the parts eliminated, so that when compared with the result of a prolonged screening they afford valuable confirmatory aid to the making of a diagnosis. Radiograms taken with time exposures can only be of value when a gross lesion is present. Another point in favour of these rapid exposures is that involuntary movements on the part of the patient are not so likely to spoil the result.

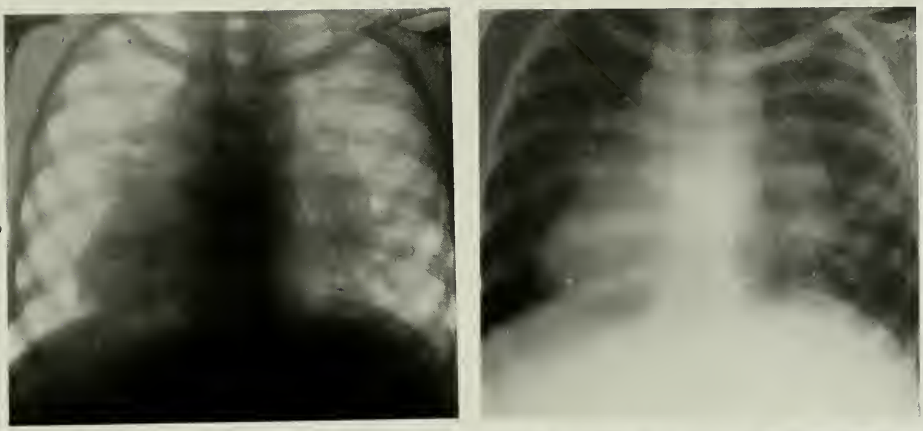
In radiography of the thorax and bones of young children there is always difficulty on account of movements during the exposures. The child has often to be held on the plate. The rapid exposure is of great value in such cases, for even when the child is moving a sharp radiograph may be obtained with an exposure of $\frac{1}{100}$ of a second. The exposure is so short that movement is practically eliminated and good detail is obtained. Short exposures are therefore particularly useful in radiography of the thorax.

Attention to Detail.—In this branch of the work, and indeed in all branches, only the most careful attention to detail in all directions will aid us in the production of reliable pictures, and a good routine is essential. Mechanical contrivances which facilitate movements of apparatus, and enable us to reproduce at subsequent examinations the same relative positions of tube, patient, and plate, will be found of the greatest service. The fluorescent screen should be adaptable for the ready insertion of the plate when an exposure has to be made. Since the work is conducted in the dark, all metal points should be insulated or the whole apparatus earthed, and all the controlling factors must be at hand. Nothing is more trying than work of this exacting nature with the factors out of order. Consequently, great care should be exercised in the selection of all apparatus, with all the features of which the operator must be perfectly familiar.

It is important for the operator to have control of the X-ray tube when

a

b



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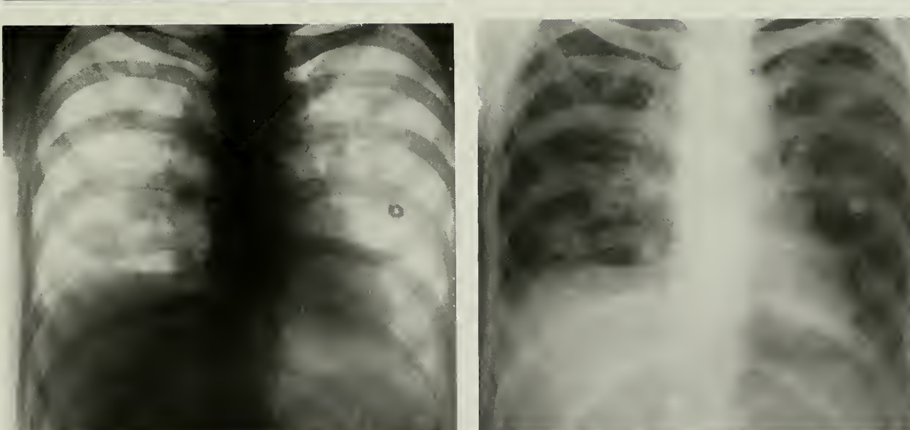
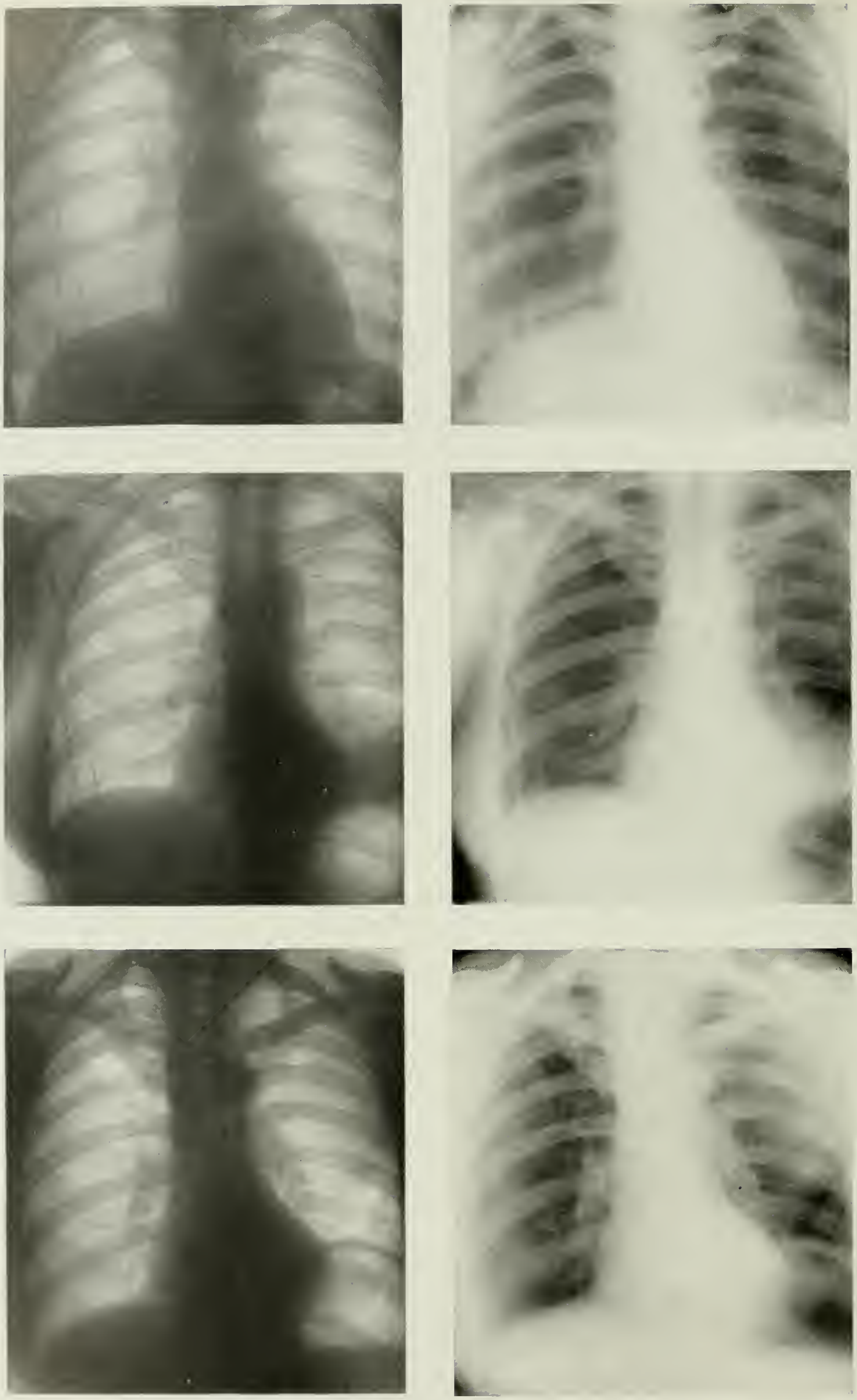


PLATE L.—MALIGNANT DISEASES OF THE CHEST.

a, Secondary deposits of sarcoma in mediastinum and lungs.

b, Lympho-sarcoma of mediastinum, extending outwards from root of lung towards the periphery.

c, Secondary deposits of cancer involving mediastinal glands, lung substance, and pleura; the diaphragmatic surfaces of the right lung and the liver are also involved.



a

b

c

PLATE LI.—THORAX SHOWING PLEURAL EFFUSION AND ITS ABSORPTION.

Three plates from the same patient at intervals of several months.

a, Plate on anterior aspect of thorax, shows practically a normal condition. Note level of diaphragm on both sides.

b, Effusion at left base. The level of the diaphragm on left side is much higher than in above plate.

c, The effusion has been absorbed but the level of the diaphragm remains higher, indicating the presence of adhesions fixing the dome of the diaphragm on the left side.

screening. A convenient form of regulator is the Bauer air-valve, a most ingenious method of admitting a small quantity of air into the bulb, the pressure of a small hand-pump forcing it through a mercury valve. By this contrivance the operator can regulate the hardness to the requisite degree without stopping the examination.

Experience in the use of the Bauer air-valve for regulation of the vacuum of the X-ray tube leads to the conclusion that unless great care is exercised in its manipulation the tube soon becomes hard, and requires to be constantly regulated when in action. Other forms of regulator may therefore be useful, such as the Osmosis regulator, where a small gas flame can be used to soften the tube. When a gas jet is used for regulating the tube it must be shaded completely when the patient is being screened. The control pump for the gas supply may be placed at a point convenient for the operator. When neither of these regulators is available the operator must regulate the tube by the usual method of sparking until it is at the proper degree of hardness for the particular case he is examining. The vacuum can then be kept more or less constant by regulating the quantity of current passing through the tube by means of the regulating rheostat. It is a good practice to commence the screen examination with the tube slightly on the hard side. A prolonged screening will reduce the vacuum, and when a radiograph requires to be taken, it will be found that the tube has attained the requisite degree of hardness. It is an advantage to keep one tube for radiography and another for screening.

The Bauer air-valve is figured in the chapter on apparatus (see page 78). The Bauer regulator is also attached to the valve tubes when these are used. The two hand-pumps controlling the valve and X-ray tubes can be placed within the reach of the operator. The control table may also be within easy reach. A foot switch to control the lighting of the room is also useful. Then the operator has all the factors under his personal control during the screen examination of the patient.

A point to be insisted on is that in every case examined a consideration of all the factors in the case is essential, and a diagnosis should never be made on the X-ray appearances alone. The physical signs are most important, and some guide should be given by the physician to the radiographer if the best value is to be obtained. The findings by X-rays are frequently only a confirmation of an opinion already formed. It is true that in some cases the extent of the disease may be greater than the physical signs indicated, or an area of disease may be shown to exist in unsuspected regions, but on the other hand radiography may fail to show a definite lesion when all the signs and symptoms strongly indicate its presence. The type of case which most frequently calls for a radiographic investigation is that of incipient phthisis. Tuberculosis of the lung in all its varieties and stages will fall to be examined, but it is the doubtful case which proves the value of radiography. Here the rapid exposures will help greatly in settling the diagnosis. The expert clinician can foretell changes which radiography may fail to demonstrate, but the fact of its failure does not negative their presence.

The expert radiographer may be more accurate than the inexpert clinician. The combination of the expert radiographer and the expert clinician cannot fail to enhance the value of the observations of each. Cases will occur when both may be wrong. Repeated examinations at intervals by both may show the changes at a later date, and the record furnished by radiography of the progressive stages of a disease must lead to the accumulation of knowledge valuable for both.

The value of repeated examinations of the thorax in some diseases is shown by the results obtained at the Cancer Hospital, London. All cases of cancer of the breast and other parts are systematically examined at intervals, valuable evidence being thus obtained of the condition of the pleura, the roots of the lungs, and the mediastinum. The progressive changes caused by secondary deposits in the pleura, the lungs, and the mediastinum are frequently shown.

Diseases of the Thorax

A brief consideration of the pathology of conditions affecting the thorax and its contents is necessary before discussing the radiographic appearances and the differential diagnosis. This review must necessarily be brief, for it is not within the scope of this work to do more than mention the various forms, with a short reference to the macroscopic appearances of such diseases, their common situations, and some points of difference in their origin and spread which have a bearing on the radiographic interpretation. The conditions that will be referred to are :

(1) Diseases of the lungs.
(2) Diseases of the pleura.
(3) Diseases of the heart.
(4) Diseases of the mediastinum.
(5) Malignant disease of the thorax, including tumours of the heart and pericardium, the lungs and pleura, the mediastinum, the œsophagus, the spine, and the chest walls.
(6) Foreign bodies in the thorax.

Diseases of the Lungs.—As these are classified and described in text-books on pathology and medicine, it will be sufficient to recall briefly the chief points which will be likely to aid the radiographer. Many of them are referred to in the section dealing with the differential diagnosis.

Circulatory Disturbances in the Lungs.—(1) *Congestion.*—Two forms of congestion are recognised, the mechanical and the hypostatic, the latter being the one most likely to show signs on radiographic examination. All grades of change may be seen passing into consolidation.

(2) *Broncho-Pneumonia.*—The lung is fuller and firmer than usual, on section, and the general surface has a dark-reddish colour. Projecting above the level of the section are lighter-red or greyish-red areas, representing the patches of broncho-pneumonia. These may either be isolated and separated from each other by uninflamed tissue, or they may be in groups, or the greater part of a lobe may be involved. The disease may pass on to the stage to

which the term splenisation has been given, when it may be accompanied by a condition of collapse of parts of the lung.

(3) *Chronic Interstitial Pneumonia* (*Cirrhosis of the Lung, Fibroid Phthisis*).—There are two chief forms, the massive or lobar and the insular or broncho-pneumonic form. In the massive type the disease is unilateral, the chest of the affected side is sunken and deformed, and the shoulder much depressed. The heart is drawn over to the affected side, the unaffected lung being emphysematous, and covering the greater portion of the mediastinum. There may be dense adhesions, and the pleural membranes may be greatly thickened. In the broncho-pneumonic form the areas are smaller, often central in position, and are found most frequently in the lower lobes.

(4) *Lobar Pneumonia* is classified by physicians amongst the specific infectious diseases, but for radiographic purposes it may be described together with the more chronic forms of pneumonia. Three stages of the process of inflammation are recognised: (*a*) engorgement, (*b*) red hepatisation, (*c*) grey hepatisation. In red hepatisation the lung tissue is solid, firm, and airless, it may be friable, and the surface has a granular appearance. Grey hepatisation is a further stage in the inflammatory process, and it may, though rarely, go on to abscess formation. The disease is usually confined to a single lobe of the lung, but the adjoining lobes may, however, be congested, and in some instances the whole lung or both lungs may become involved.

(5) *Tuberculosis of the Lungs.*—All forms may be met with.

Diseases of the Pleura.—These require to be briefly considered, because the occurrence of one or other of them may give rise to a difficulty in diagnosis; and also in the course of a malignant tumour of the lung, pleurisy and effusion are common sequelæ. The simple form of pleurisy is easily recognised. Hæmorrhagic pleurisy may occur when carcinoma of the lung is present. Diaphragmatic pleurisy may be limited partly or chiefly to the diaphragmatic surface. It is often dry, but may be accompanied by effusion, either serofibrinous or purulent, which is circumscribed to the diaphragmatic surface. Serous or purulent effusions of any size confined to the diaphragmatic surface are very rare. Encysted pleurisy may lead to a loculation of the resulting empyema, which will give a shadow that may be quite indistinguishable from that caused by a new growth or a primary abscess of the lung. Interlobar pleurisy is another condition which must be borne in mind when considering a doubtful negative.

Diseases of the Heart.—Tumours of the heart are rare, but there are conditions which may simulate tumour, and which must, therefore, be mentioned. These are tuberculosis and syphilis.

Tuberculosis of the Heart.—This occurs as: (*a*) scattered miliary tuberculosis; (*b*) large caseous tuberculosis, extremely rare; (*c*) sclerotic tuberculous myocarditis. The disease generally proceeds from a mediastinal gland, this fact being important from a radiographic point of view.

Syphilis.—Gummata are the only manifestations of this disease likely to attract the attention of the radiographer in the cardiac region.

Diseases of the Mediastinum.—In simple lymphadenitis and suppurative lymphadenitis, the glands are large and infiltrated, but are not usually dense enough to cast shadows sufficient to complicate a diagnosis. Suppurative lymphadenitis may, however, lead to abscess formation, and then a large shadow may be found due to the presence of pus. Both these conditions may simulate tumour. Abscess of the mediastinum is not at all uncommon, and may be of considerable size. It is secondary to an infective process, *e.g.* erysipelas, eruptive fevers, and tuberculosis. Indurative mediastino-pericarditis is a condition in which the pericardium may be greatly thickened by a great increase of the fibrous tissue. This may give rise to changes in the mediastinal shadows.

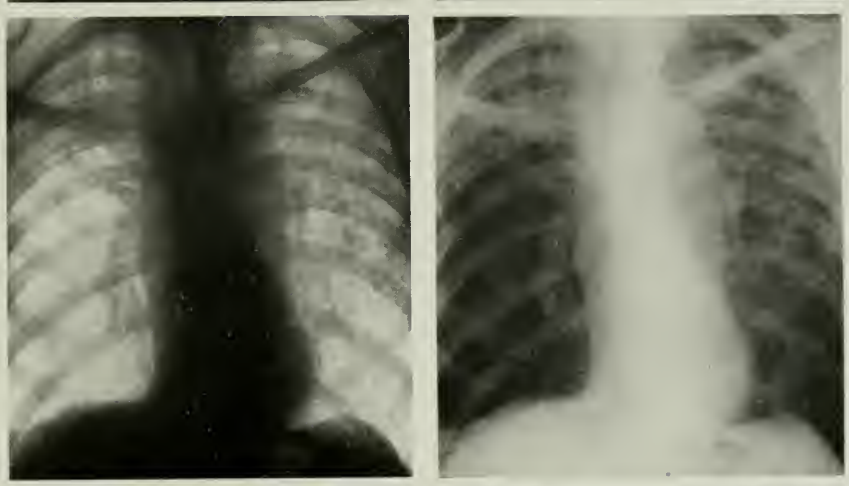
Malignant Diseases of the Thorax.—The tumours most commonly met with will be considered first, then the rarer conditions, and finally tumours involving the bony structures composing the walls of the thoracic cavity, namely, the vertebræ, ribs, sternum, and costal cartilages, will be briefly considered.

Tumours of the Heart are very rare. An enlarged, hypertrophied, or dilated heart may, however, complicate a diagnosis when a malignant process is situated in the near vicinity. Primary cancer and sarcoma are extremely rare. Secondary tumours—sarcomata and carcinomata—may occur, either directly or by extension from the pleura and pericardium. Calcareous patches occurring in a greatly dilated aorta may, where viewed laterally, simulate the appearance of secondary growths in the mediastinal glands. When these occur the outline of the dilated aorta is seen as a rule, particularly if there is an associated condition of arteriosclerosis, and these shadows should therefore be capable of differentiation from the more serious condition of growth. A hydropericardium may lead to difficulty when the pleura also contains fluid, both of these structures becoming involved when there are secondary deposits of malignant disease in the pleura.

Tumours of the Lungs and Pleura.—Primary tumours are rare, and primary cancer or sarcoma as a rule involves only one lung. Secondary growths are not uncommon, and may be of various forms, generally following tumours of the digestive tract, the genito-urinary organs, or the bones, and, most frequently of all, cancer of the breast. The types most usually met with are in order of frequency : (1) scirrhus cancer ; (2) epithelioma, which may be primary in the bronchial tract ; (3) sarcoma ; (4) fibroma ; (5) enchondroma ; (6) osteoma (very rare). The lungs may also be involved in Hodgkin's disease. The primary growth generally forms a large mass, which may occupy the greater part of the lung. It may by extension outwards involve the parietal and visceral pleura. The tumour mass may necrose, and a cavity result. The diffuse cancerous growth may resemble a tuberculous pneumonia. The metastatic growths are nearly always disseminated ; they may vary from a miliary type to quite a large growth, and all variations in size may be met with in the same patient. The symptoms may be slight or marked according to the accessory lesions which accompany the new growth, such as pleurisy ; this may be dry or accompanied by effusion.

a

b



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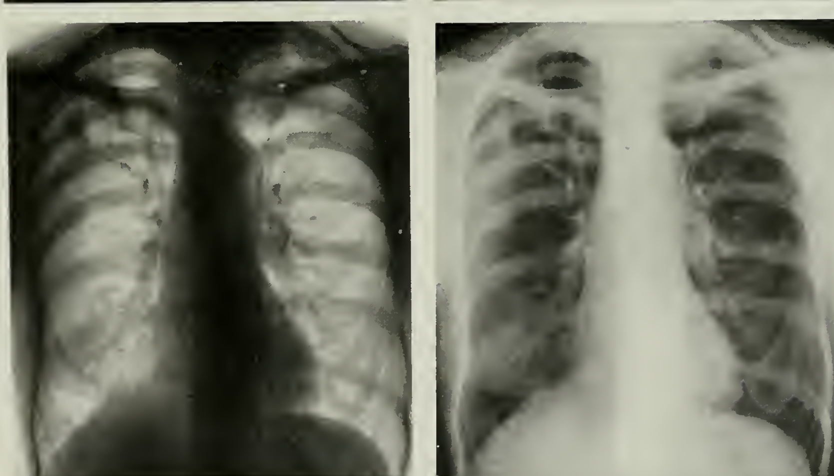


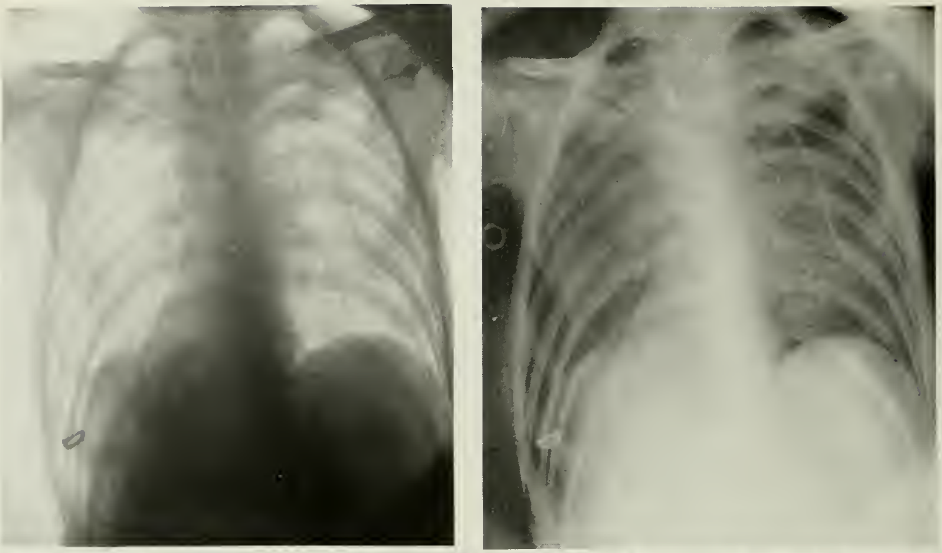
PLATE LII.—RADIOGRAMS SHOWING PULMONARY TUBERCULOSIS.

a, Right apex showing advanced consolidation ; left apex involved but disease not so advanced ; roots of lung both involved but more so on right.

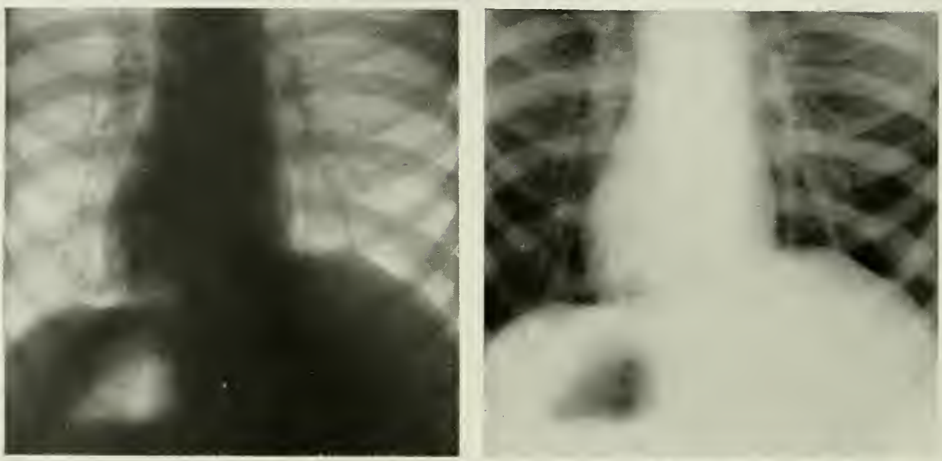
b, Left side of chest extensively involved ; both apices are involved ; heart small and "vertical." These two cases are both affected by active tuberculosis.

c, Healed tuberculosis of long standing ; both apices show signs of involvement : roots of lungs show evidence of calcified glands. Patient had no active symptoms.

a



b



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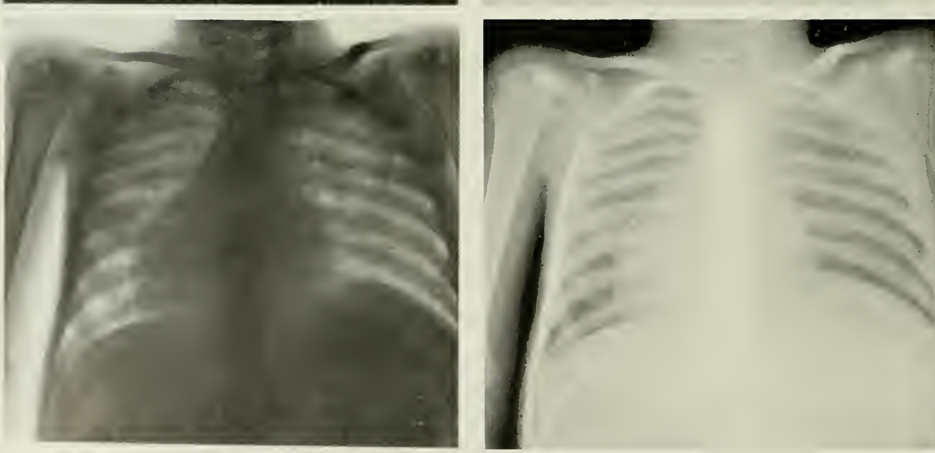


PLATE LIII.—RADIOGRAMS SHOWING PULMONARY TUBERCULOSIS.

a, Post-mortem subject. Note fine shading in lung substance. Tuberculous broncho-pneumonia.

b, Early tuberculosis of lungs, peribronchial thickening, irregularity of diaphragmatic shadow on right side, with sharpness of all detail. Exposure $\frac{1}{100}$ second, intensifying screen used.

c, Acute general tuberculosis of both lungs (miliary tubercle).

Tumours of the Mediastinum.—Cancer is the most common form of tumour in the mediastinum. There are three chief points of origin: the thymus, the lymph glands, and the pleura and lungs. Primary sarcoma is more frequent than primary cancer. Lympho-sarcoma and lymphadenoma frequently give rise to large tumours.

Tumours of the Œsophagus.—The most common tumour is epithelioma, and it occurs more frequently in males than females. The middle or the lower third of the œsophagus is the most usual situation in which the growth is found. It is at first confined to the mucous membrane, but soon breaks through and extends into the mediastinal tissue, stricture occurring in the lumen of the tube. Later on, when ulceration of the mucous surface occurs, the stricture may be less marked than in the earlier stages. In the course of the disease the œsophagus above the growth becomes dilated, and a degree of hypertrophy follows. The ulcer may perforate the trachea, the lung, the pleura, the mediastinum, the aorta or one of its branches, or it may erode the vertebral column.

FIG. 248.—Post-mortem specimen mediastinal tumour. Lympho-sarcoma.

Tumours of the Spine.—Tumours, simple or malignant, may arise in connection with the spine, the ribs, the intercostal spaces, and the costal cartilages. These may by extension involve the adjacent organs, and when the lungs and pleura become implicated shadows are obtained which are indistinguishable from new growths of primary origin in those structures. Conditions involving the spine which may lead to error are: (1) Tubercular caries. In the early stages an inflammatory process leads to thickening and abscess formation which simulate new growths of the spine; rise of temperature and other signs of tuberculosis should be looked for. (2) Abscess following caries is a frequent cause of difficulty in diagnosis. (3) Sarcoma arising from the costal cartilages and sternum may lead to the formation of a definite cystic condition indistinguishable from hydatid cyst. A hæmorrhagic condition in the tumour may simulate the appearance presented by a cyst.

Tumours of the Chest Walls.—Sarcomata in these positions are occasionally met with. They may be solid, or, when growing rapidly, may become cystic or hæmorrhagic, and when examined show shadows which may be mistaken for new growths of the lungs or pleura.

Foreign Bodies in the Thorax.—Various forms of these may be met with, particularly in children. A foreign body should first be located by means of the screen, and stereoscopic radiographs taken for exact localisation. If an operation is contemplated, then the examination should be repeated just prior to the time of operation, in order to obviate the risk of change of position of the foreign body. The thorax and cervical region require to be carefully examined when a foreign body is suspected to be present. Lateral pictures are useful, particularly when the foreign body is located in the upper air passages.

Differential Diagnosis in Diseases of the Lungs

The differential diagnosis of these conditions is always difficult, particularly from a purely radiographic point of view. The X-ray findings are usually shadows of abnormal growths, invading shadows representing the normal structures, and it is often on slight variations of these normal shadows that a diagnosis may be made. A fine departure from the normal may be the earliest manifestation of a commencing new growth, and its presence may be detected before physical signs or symptoms call attention to the presence of serious mischief. On the other hand, however, it is occasionally found that persistent symptoms, such as pain, slight cough, dyspnœa, may be present for months before the presence of a neoplasm can be detected by radiographic examination. This is particularly evident in the *recurrent forms of carcinoma* after operation, where pain at a fixed point may for a very long time be the only sign of recurrence. Later this may be followed by the demonstration of a gradually increasing shadow, or a slowly accumulating pleural effusion, indicating that the pleura has become involved. The occurrence of these infiltrating secondary carcinomata of the pleura is interesting. The extension is usually by direct continuity from the chest wall, the growth developing through the intercostal spaces, slowly involving the pleura on the parietal aspect, spreading along the internal aspect of the ribs, and forming flat plaques which do not penetrate to any degree. These plaques are shown as fine shadows along the lines of the ribs. Fluid is slowly exuded into the pleural sac, and, later, the visceral layer of the pleura becomes involved, at a still later stage the lung itself becoming invaded by masses of slowly increasing size. In contradistinction to this it must be borne in mind that the secondary invasion of carcinoma may begin in the mediastinal glands or those at the roots of the lungs. It then spreads along the bronchial glands, and at a late stage of the disease we may find the pleura studded with plaques on its parietal and visceral aspects, with an accumulation of fluid in the pleural sac, the mediastinal glands enlarged, and the whole of the lung riddled with growths of various sizes. Radiographically, all these stages of secondary carcinoma may be shown in the same case if examinations are made during the progress of the disease. The various progressive stages of this form of malignant disease are well worthy of careful study, for all these forms are sure to require investigation. In the earlier stages it is extremely difficult to establish a diagnosis on radiographic evidence alone ; all the facts of the case require careful consideration, and other methods are helpful, particularly in some cases where tuberculosis may be the alternative diagnosis, or where it may be an accompanying condition. The combination of the two diseases is rare, but they may occur in the same patient. Hæmoptysis may be a determining factor in the diagnosis, especially if it occur to any extent. Hæmorrhage to a marked extent from a secondary carcinoma is comparatively rare, whereas in tuberculosis it is often the first symptom to call attention to the disease.

Simple Tumours of the Lung.—These are very rare. Tumours of the chest wall are fairly common, and may give rise to shadows which have to be differentiated from tumours of the pleura and lungs. Such tumours may be enchondromata of the costal cartilages and bones. Osseous tumours will give dense shadows, and should present no great difficulty in diagnosis.

Primary Malignant Growths of the Lung.—These are rare, but they do occur, and when a shadow is seen in the thorax, in a case which gives no evidence of a primary lesion elsewhere, the assumption is that it may be a primary malignant growth. Before the diagnosis is made, however, every care should be taken to investigate for a primary lesion, and the whole thorax should be carefully examined, particular attention being paid to the larynx, trachea, and œsophagus. Primary growth in the œsophagus is frequently not examined until late in its course, or until the presence of secondary deposits in the mediastinum calls attention to it. A large endothelioma may develop in the mediastinum, and invade the lung to a considerable extent before giving rise to any symptoms. Tumours of this type are of singularly slow growth, and tend to become encapsuled. The shadow given by these tumours will be well defined, and may simulate an aneurism.

Fig. 249.—A case of slowly growing mediastinal tumour—probably endothelial in origin—which gave rise to practically no symptoms other than slight shortness of breath.

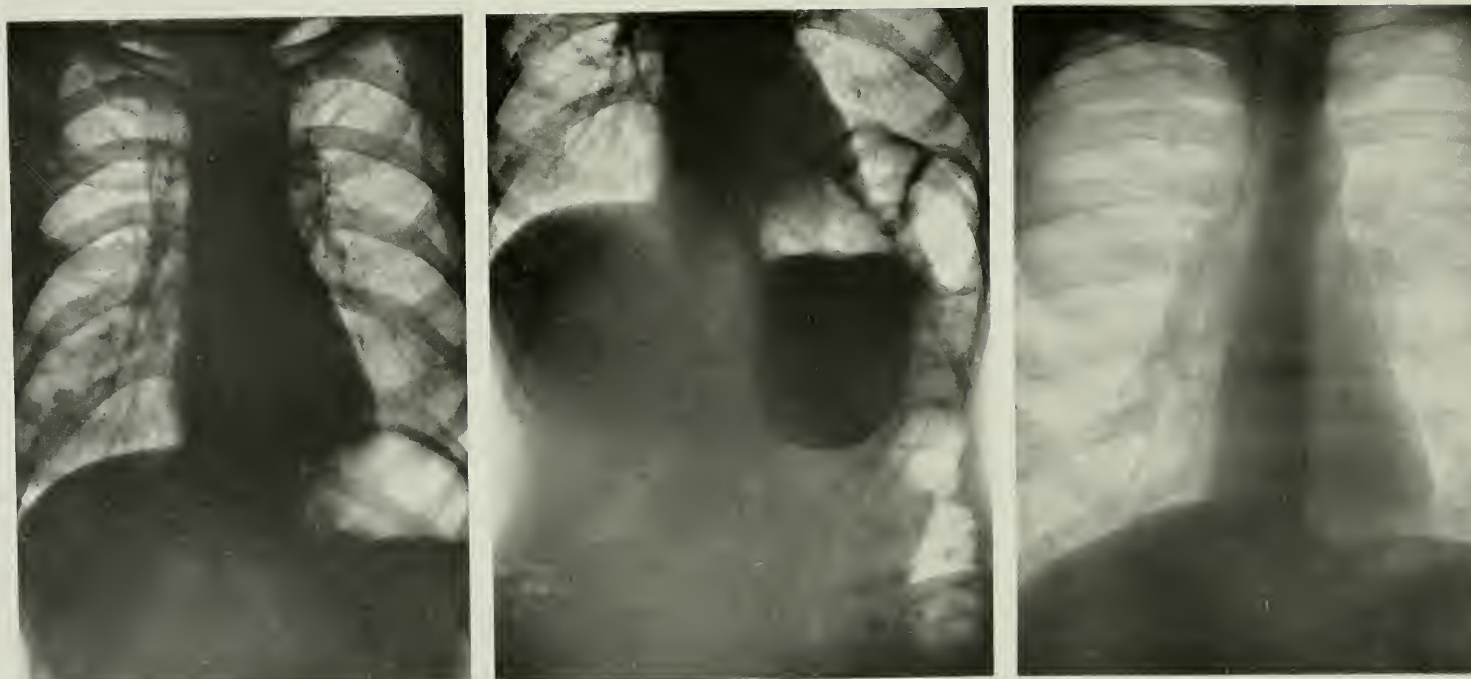
Hodgkin's Disease.—This produces well-defined shadows in the mediastinum, and when the bronchial glands are involved these give rise to shadows which may simulate malignant growth. The shadows from a simple enlargement to a most pronounced type of sarcoma are finely graded, and any of these may present appearances indistinguishable from a well-marked malignant invasion. Time and clinical observations will help to clear up the diagnosis.

Lympho-sarcomata.—Malignant growths arising in connection with and having the structure of lymphatic tissue are not infrequently found in the mediastinum, invading the root of the lung. They tend to produce metastases, and may be very malignant; when well advanced they lead to rapid emaciation.

FIG. 250.—A case of lympho-sarcoma of the mediastinum, extending outwards into the lungs on both sides.

Sarcoma of the Lung.—This generally arises in the glands of the mediastinum, and spreading into the lung substance by direct extension, the tumour tends to become solid, and may eventually compress the lung towards the periphery. Sometimes there is a rapid spread of metastases all over both lungs. This type of tumour is frequently secondary to a lesion elsewhere. From a radiographic point of view it is often impossible to distinguish between sarcoma and endothelioma and secondary carcinoma. The history of an operation for removal of carcinoma or sarcoma of another part of the body will often settle the diagnosis. A rapidly growing sarcoma may be disseminated all over the lung and pleura, but in the early stages the nodules will be small, and may simulate a miliary tuberculosis.

The clinical history is generally shorter in acute phthisis than in sarcoma. In secondary carcinoma the nodules are generally larger, tend to become more irregular, and may in early stages be more located to the periphery or central portions of the lung, while the presence of pleurisy or a chronic pleural effusion should help in the establishment of a diagnosis. An acute lobar pneumonia will give a well-defined shadow, generally confined to one lobe or a part of a lobe of the lung. A few days will suffice to clear up the diagnosis, but when the pneumonic process is slow to resolve, and the lung tends to fibrosis, then a condition arises which may lead to serious errors in prognosis if full consideration is not given to all the facts of the case. Other forms of pneumonia may lead to difficulty in diagnosis, and it must be remembered that a patient suffering from primary or recurrent cancer is in a debilitated state of health, and in consequence rather prone to develop broncho-pneumonia. This may be a terminal stage of the disease, even when recurrence has located itself in the lung; the apparent extent of the mischief may be greatly exaggerated by a concurrent attack of broncho-pneumonia. When radiographs of such a condition are taken, a grave error in prognosis may be made if a large shadow in the lung substance is mistaken for a malignant deposit; further, the subsequent resolution of a pneumonic process may give the impression of an improvement in the condition of the patient, and a subsequent shrinkage of the shadow may lead to the erroneous conclusion that the tumour itself is disappearing. Similarly a pleural effusion,



a *b* *c*

PLATE LIV.—RADIOGRAMS SHOWING IN *a* AND *b* PERIBRONCHIAL THICKENING AT THE ROOT OF LUNGS AND IRREGULARITY OF LEFT SIDE OF DIAPHRAGM.

a, Taken when diaphragm was displaced upwards by gas in stomach.

b, Same case taken with opaque meal in stomach (hour-glass)? Note great irregularity of diaphragm caused by gas in stomach and colon.

c, Single impulse exposure of another case, showing very sharp detail particularly of the left border of the aorta and heart, with marked peribronchial thickening of right root.

a

Lung, silicosis. (Dr. J. D. Comrie's collection.) ½.

Raised, hard, grey areas, surrounded with black pigment, scattered in groups under pleura, around vessels and bronchi, and along interlobular septa.

b

Section of lung showing large number of nodules of secondary carcinoma. ½.

c

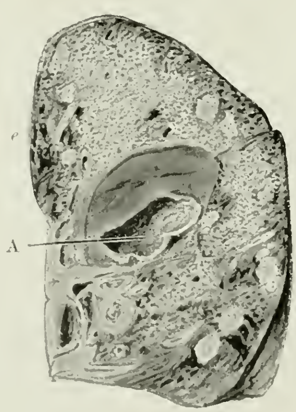
Mediastinal glands and lung of infant. ½.

d

Lung, caseous (tuberculous) pneumonia with cavitation. ½.

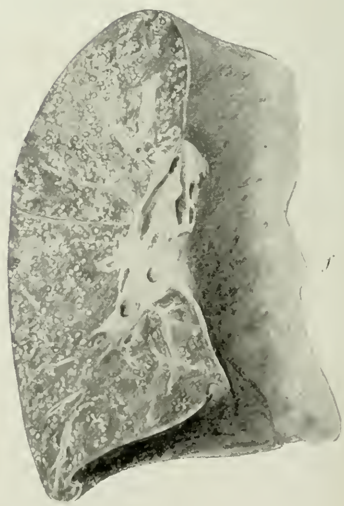
There is caseous consolidation of the upper portion, with numerous acute cavities. In the lower portion there are groups of tubercles arranged in a staphyloid manner indicating lymphatic spread. The pleura is thickened.

e



Lung, chronic tuberculosis with cavity in which an aneurism (A) has formed. ½.

f



Lung, acute miliary tuberculosis. ½.

Minute grey tuberculous foci irregularly scattered through the lung.

PLATE LV.—POST-MORTEM SPECIMENS TO ILLUSTRATE CONDITIONS OF THE THORAX WHICH ARE FREQUENTLY MET WITH IN THE ROUTINE EXAMINATION.

From Miller's *Practical Pathology, Morbid Anatomy, and Post-mortem Technique* (Black).

with thickening of both layers of the pleura, may give the impression of an actual new growth in the lung. Tapping of the pleural sac and withdrawal of the fluid, with a resolution of the inflammatory process, may be another source of error in diagnosis and prognosis. Hæmorrhage into the lung substance may also simulate a growth of considerable size.

Infarction of the Lung (Pulmonary Apoplexy).—This condition comes on suddenly, and may be accompanied by pain and signs of pulmonary embarrassment. The examination of a patient after the symptoms have subsided may show a fairly well defined shadow in the lung substance, which gives rise to grave suspicions when the patient is already the subject of a cancerous invasion.

Tuberculosis.—As already stated, tuberculosis of the lung may be met with in all its stages, the later stages being readily recognised by the gross departure from the normal. In very early or incipient cases of phthisis it is more difficult to make positive statements, but the combined findings of the clinician and radiographer are most helpful.

The various forms of tuberculosis met with in the pulmonary system require to be dealt with in the differential diagnosis. Cases with enlarged bronchial glands will cause some difficulty. The peribronchial forms of phthisis give rise to marked increase of the hilus shadows, which are extremely difficult and often impossible to differentiate from new growth. The chief point of distinction between the two lies in the fact that in the peribronchial form of phthisis the increase of shading is more evenly distributed at both roots, and may extend up to the apex or down to the base of the lung, forming " tree root " shadows, with nodular enlargements of small size, the latter indicating the presence of calcified or fibrosed bronchial glands. When a recurrence of cancer occurs at the roots of the lungs it tends to be more definitely localised to one spot, and spreads outwards into the lung substance, while the remaining portion of the bronchial tree on that side may show no marked increase. The bronchial ramification on the other side is generally free. A bilateral increase of shadows is more in favour of a tuberculous condition than a malignant growth. The tuberculous condition may, however, be present in a patient who subsequently develops a cancer or a sarcoma of the lung.

Figure 251 illustrates an important point in diagnosis. The patient, about fifty years of age, was sent for treatment of a tumour of the breast, and the radiation treatment cleared up the tumour. Some doubt arose in the writer's mind regarding the nature of the tumour. Inquiry into the history of the patient elucidated the fact that she had thirty years before suffered from " a severe lung attack." Screen examination revealed the condition shown, viz. a large area of irregular increased density at the right base. The condition is strongly suggestive of a healed tubercular affection of the lung and pleura with calcareous deposits in the tissues. This confirms the doubt as to the true nature of the breast tumour. The case has now been under observation for two years and the breast remains normal.

When disease has been shown to be present, it is often difficult to determine whether it is active or not. The distinction between *active* and *healed* tuberculosis has often to be made. In the former the mottling of the lung shadows is more marked, in the latter the appearances conveyed are more those of streaking, indicating a fibrotic condition. In some cases the shadows appear to be denser, and occasionally it is possible to make out areas of calcification. These may be seen at the apices, but more frequently at the root of one or both lungs.

Fig. 251.—A case of long-standing lung disease. The patient was about 50 years of age, with a history of a severe pulmonary attack 30 years before.

Jordan has drawn attention to the appearances of the hilus shadows when he states that a great number of cases examined showed peribronchial thickening. He ascribes this condition in nearly every case to the presence of tubercle, and states that nearly all the cases he examined showed a condition of this kind. When these bronchial shadows are accompanied by mottling the condition is said to be active. He also contends that in the majority of cases the disease started at the hilus by an infection of the bronchial glands, and an extension from these glands takes place towards and involving the apex.

Bythell records the results of an examination of several hundreds of children. He found in a large percentage of these cases signs of tuberculous infection in the glands at the roots of the lungs.

While admitting that in the examination of a large number of chests these shadows are to be seen, the writer cannot agree that a diagnosis of tuberculosis can be made in every case. It is quite probable that other conditions than tuberculosis will give rise to peribronchial thickening. Thus chronic bronchitis, asthma, and any disease which leads to chronic irritation of these parts, may cause an increased formation of fibrous tissue around the bronchi; the repeated inhalation of dust and smoke, which is a concomitant of dwelling in towns, might quite easily cause a peribronchial thickening. These peribronchial shadows are frequently present in the chests of patients who are suffering from cancer, but it would be absurd to argue that in every case these increased shadows indicated the presence of a peribronchial invasion by cancer cells. Nor would it be reasonable to assume that the victims of cancer were also afflicted with tuberculosis.

The appearance of the chest shadows in many patients known to have cancer is strongly suggestive of peribronchial phthisis. It must be borne in mind that both diseases may be present in the same patient. It is quite possible that some of the patients may have had phthisis in early life, and what we see later are changes caused by the healing in the lung tissue. In the opinion of the writer there is undoubtedly a large number of cases, especially among patients at middle life or later, where the excess of fibrous tissue leads to very definite peribronchial shadows, which are due entirely to the thickening around the bronchi, and are diagnostic neither of tuberculosis nor cancer. In many of these cases the thickening of the bronchus may be seen on cross-section. It frequently happens, especially on the right side of the chest, that one or more nearly circular rings are shown. These are caused by a cross-section of the bronchus, where it bends nearly at right angles on its way to the deeper part of the lung.

FIG. 252.—Thorax of child, age about 12 years. Peribronchial thickening, with calcareous deposits in the glands at the roots of lungs.

The thickening is clearly seen in the right side, and on the left side can be seen through the heart shadow, extending down to the dome of diaphragm.

The radiograph in Plate LVII., Fig. *b*, well illustrates the peribronchial thickening; it is from a case of malignant disease and the branching of the bronchi is very well seen. The patient did not suffer from phthisis, nor had she any secondary deposits of cancer at the roots of the lungs. The grosser manifestations of tuberculosis of the lung require no lengthy description. A few radiographs will illustrate the appearances met with.

Cavities may readily be shown, especially when they are large and contain air, though the localisation of a small cavity in an area of consolidation is not always possible.

It must be borne in mind that other conditions than tuberculosis give rise to appearances identical in every respect. *Actinomycosis* of the lung in the earlier stages is practically indistinguishable from a widespread tuberculous infection. In the later stages, however, more marked changes in the former might lead to a correct diagnosis. The nodules tend to become coarser than in miliary tuberculosis, and the tendency to suppurate should put us on guard when examining a suspicious case. It should also be noted that in actinomycosis the tendency is for the disease to spread and involve the pleura, while localised abscesses of the chest wall would also occasionally occur.

The early stages of a sarcoma, when widely spread through the lung substance, might readily be mistaken for a miliary tuberculosis, but even in these early stages the occurrence of a rise of temperature in tuberculosis should be sufficient to lead to a correct diagnosis. In the later stages the small centres of growth rapidly increase in size, and appear to be much larger and coarser in structure than in tuberculosis. The history of the patient is also a help, as is also the presence of a primary lesion in other parts of the body.

Plate L., Fig. *a*, illustrates the mediastinal glands and lung substance in a boy aged six, who two years before had had his arm removed on account of a primary growth in the humerus. The secondary extension can be well seen in the glands and lung substance. The primary growth of the humerus is seen in Plate XLVI., Fig. *a*.

Syphilis.—Syphilis of the lung or bronchi may cause some difficulty in diagnosis, especially if there be a tendency to the formation of gummata, which might be mistaken for new growth or deposits of tubercle. The history of the case and a positive Wassermann reaction should clear up the diagnosis.

Pneumonia.—Acute lobar pneumonia, when well defined, is characterised by a large, comparatively dense shadow, occupying the portion of the lung involved. It may be quite localised to one lobe, or may involve the whole of one lung, while the other lung may show signs of congestion. It may be accompanied by a pleural effusion. The clinical history and the feverish state of the patient should give a clue to the nature of the disease, and the subsequent resolution of the inflammatory process, with the slow subsidence of the shadow seen on radiographic examination, will help to clear up the diagnosis. An acute pneumonia may, however, not resolve quickly, and a shadow in the substance of the lung may be visible for several weeks after the inflammatory symptoms have subsided. Later on the affected portion of lung may become fibrosed. It is this class of case which gives rise to great difficulty in radiographic diagnosis. Acute broncho-pneumonia, when occurring in children, is another condition which leads to great difficulty in diagnosis, especially as an acute miliary tuberculosis gives nearly the same appearances on radiographic investigation.

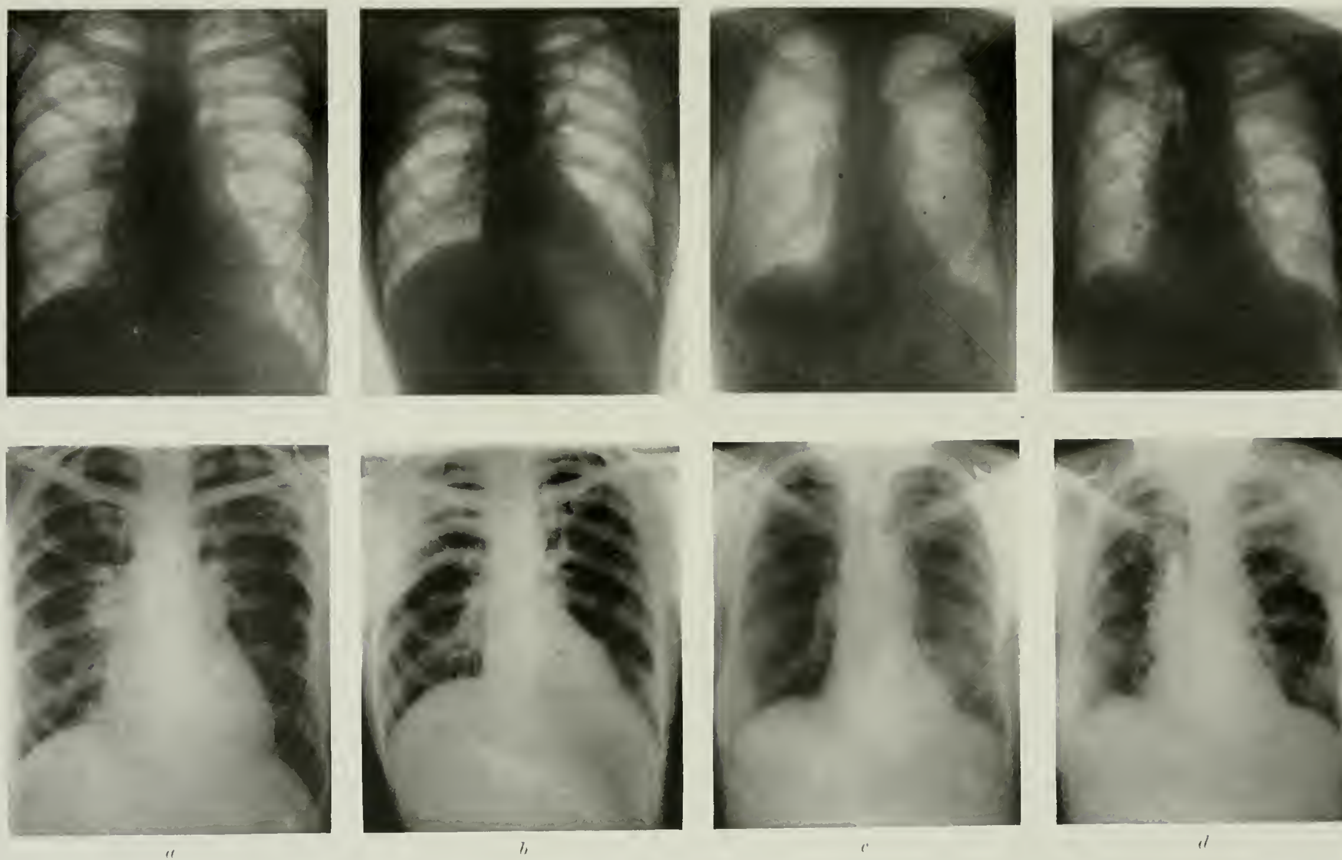


PLATE LVI.—CHESTS SHOWING SECONDARY CARCINOMA.

Radiographs from patients who had been operated on for cancer of the breast; all four patients had recurrent growth in the thorax; these were observed at various stages of the disease. *a*, Secondary deposit of cancer at root of right lung, spreading out from the mediastinum. *b*, Secondary deposit at root of right lung. *c*, Widening of mediastinal shadow in upper part, occurring in a patient who had the breast removed for cancer. *d*, Enlarged glands in mediastinum; patient has been slightly rotated to one side to show the glands.

Interstitial Pneumonia.—The forms of interstitial pneumonia which result in an increase of the fibrous tissue of the bronchi and lungs may also give rise to difficulties of diagnosis. The most commonly met with are : (1) Those following an acute pneumonia ; (2) those due to inhalation of dust ; (3) those due to the chronic action of bacterial poisons, *e.g.* tuberculosis, syphilis, actinomycosis.

Pneumonokoniosis.—Interstitial pneumonia due to the inhalation of dust. There are three varieties of this according to the type of dust inhaled : (1) Anthracosis, coal-miners' lung ; (2) silicosis, stone-masons' lung ; (3) siderosis, needle-grinders' lung. In all these forms the foreign particles are inhaled and absorbed by the lymphocytes. They are deposited along the course of the lymphatics, forming nodules, and tending by chronic irritation to a marked degree of fibrosis. The lymph-glands are enlarged and indurated. In all these types the distinguishing feature, in contradistinction to that of malignant disease, is the more uniform distribution of patches of induration all over the lung and bronchial tracts.

Abscess of the Lung.—Abscess of the lung is occasionally met with, an area of consolidated lung tissue surrounding a central opacity. Radiographically, the appearances may simulate new growth, and an exploratory operation may be the only definite way of establishing a correct diagnosis.

Bronchiectasis.—This condition may be found in patients also suffering from chronic bronchitis and tubercular and malignant disease. A marked degree of dilatation and peribronchial thickening may cause shadows which are sometimes indistinguishable from those caused by a localised new growth.

The value of radiography and radioscopy in cases of bronchiectasis lies in the demonstration of a degree of dilatation of the bronchi and the presence of an accumulation of mucopurulent secretion. It is necessary to be able to locate these accumulations for the guidance of the physician. The thorax should be examined when the secretion has been expectorated, and later, after time has elapsed, re-examined for the reaccumulation of secretion. The patient should be given several doses of morphia, when it may be possible to show the dilated bronchi filled with secretion.

Differential Diagnosis in Diseases of the Pleura.—Acute pleurisy is frequently characterised by an effusion of serum into the pleural cavity.

Serous pleural effusion is readily recognised. It may obscure the whole of the lung shadow, or the lung may be pushed upward and inward towards the middle line.

Chronic Pleurisy.—When this involves the parietal and visceral layers considerable thickening of the pleura may ensue, and this may lead to a degree of compression of the lung which may give the impression of a malignant growth.

Secondary cancerous deposits must also be looked for. The pleura is most frequently involved in these cases, thickening at the bases with or without an effusion being frequently met with, or the growth may extend outward to the lung substance. The earliest manifestation of a recurrence of cancer may be found in the pleura; the mode of invasion is described on page 288. Radiographically, the recurrence may be shown as fine irregular opacities on the inner surface of a rib, and spreading along the pleura covering the rib, involving also the pleura covering the intercostal muscles. The shadow may show merely an increase in striation of the pleura, or it may appear as comparatively dense plaques. The mediastinal glands may be involved, being seen at the hilus of one or both lungs, where discrete glands may be demonstrated. The anterior mediastinum is occasionally involved, and in order to show these deposits it is necessary to take an oblique lateral view, when the enlarged glands may be seen just behind the sternum. Glands in the axilla and in the supraclavicular areas may also be met with, and should be shown on radiographic examination.

Fig. 253.—Thorax of adult showing pleural effusion at the right base.

Purulent Effusion, Empyema.—This may readily be recognised. The shadow is very dense, and limited more or less according to the amount of pus present. Localised empyema may give appearances of a like nature, especially when the process is interlobar. Empyema which has been drained and followed by collapse of the lung is another condition which must be considered. The presence of an opening into the pleural sac will be a guide as to the nature of the case, but when a doubt exists, the cavity may be injected with bismuth emulsion and its exact size determined.

Abscess of the Lung is sometimes met with apart from an empyema. It may be deep-seated and very difficult to determine.

Pyo-pneumothorax.—Pus is present in the lower part of the pleural sac. A clear area is seen above the level line of pus, and lung tissue above the clear space.

Foreign Bodies in the Pleural Cavity.—Occasionally a drainage tube gets into the pleural cavity after an operation for draining the pleura. This can readily be located. Efforts for removal may be facilitated by a screen examination, and the forceps guided to the tube.

Irregularities in the Outline of the Diaphragm, to whatever cause they may be due, will often give appearances which lead to difficulties in diagnosis; moreover, a secondary involvement of the liver is not at all uncommon in cases where a growth in the lung exists.

Tumours of the chest wall may also have to be excluded.

Hydatid cyst, though not common in this country, must not be overlooked. The appearance of such a cyst is diagnostic, and a rounded, sharply cut shadow in any part of the lungs should excite suspicion of hydatid disease. Cysts may arise from any of the structures composing the walls, *i.e.* sternum, ribs, costal cartilages, or spine. The appearances presented by a case of primary sarcoma arising from the inner aspect of a rib are typical of cyst—a rapidly growing sarcoma, which becomes hæmorrhagic, the walls of the growth consist of thickened pleura, and the cavity is filled with blood-clot and growth. The X-ray appearances will show it to have a well-defined wall with semi-fluid contents.

The Examination of the Heart and Aorta

Variations in the Size, Shape, and Position of the Heart.—The heart may be greatly enlarged in all directions, or it may show a marked hypertrophy of the left ventricle. Dilation of the right side of the heart may be distinguished from hypertrophy by the lack of density in the shadows.

The heart may be displaced to one or other side. It is sometimes seen on the right side of the thorax, the aorta in such a case bearing down to the right of the middle line.

The radiographic appearances of hydropericardium are characteristic. The cardiac outline is greatly enlarged in all directions, and there is a marked increase in the breadth of the shadow. It is bulged out, and gradually lessens in size towards the base of the heart, the shadow appearing to be widened at the apex where the heart rests upon the diaphragm. The outline of the heart may be faintly seen through the shadow caused by the dilated pericardium. The usual pulsation of the heart is lost or only seen faintly at the apex.

There are many variations in the appearance of the heart-shadow which have a definite significance in diagnosis. The small " nervous " heart of the neurotic patient is characteristic. In thin patients the contractions of the heart can be plainly seen, while in some instances, where there is irregularity in the heart-beat, the intermissions may be observed on the fluorescent screen. Similarly, in cases of Stokes-Adams disease, where there is a slowing of the pulse with alterations in the cardiac rhythm, these phenomena may readily be seen on the screen. The vertical heart seen in many cases of tubercle of the lungs is also a recognised feature in the radiography of the thorax. The heart may be enlarged irregularly in syphilis, gummata may cause shadows which might be mistaken for other conditions, and aneurism of the heart may cause an irregular shadow indistinguishable from gumma or new growth. The heart may also be the seat of a malignant neoplasm which may be primary or secondary to a lesion on the lungs, pleura, or mediastinum.

Cysts in the heart are rare, but the possibility of their occurrence should be kept in mind when an abnormal shadow is seen on the cardiac area. Hydatid cyst is extremely rare in this situation.

Screen examination of the heart is often very serviceable in diagnosis; the organ may be seen pulsating and the phases of the cardiac cycle studied.

Thoracic Aneurism.—The screen examination is very important, and should be employed in every patient sent for diagnosis. A radiograph is necessary also, but in this, as in all thoracic examinations, it must be insisted upon that the plate is merely a permanent record of what we see on the screen, and only a phase of what can be seen when a thorough screening is carried out.

The patient must be examined in at least three positions: (1) antero-posterior; (2) postero-anterior; (3) right lateral oblique, in which the patient faces the screen, and turns half round towards his right. In the first two positions the heart is well seen, but the normal aorta is almost entirely masked by the central opacity formed by the spine behind and the sternum in front, with the exception of the left lateral aortic bulge, which is not evident in all cases.

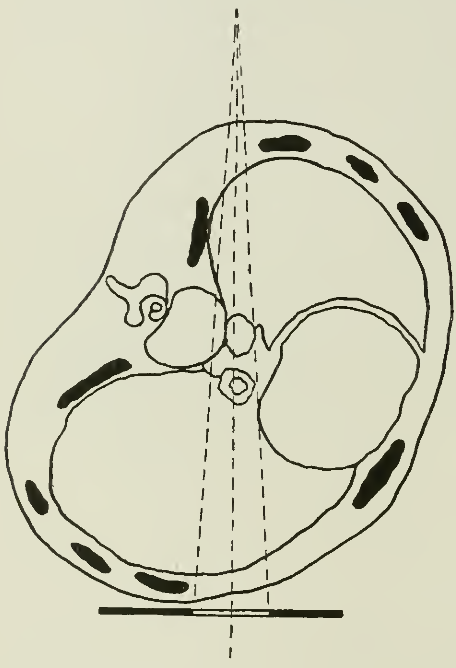


Fig. 254.—Position of thorax for lateral oblique position, to show position of plate and source of X-rays. This is a useful position for the examination of the aorta, œsophagus, and mediastinum.

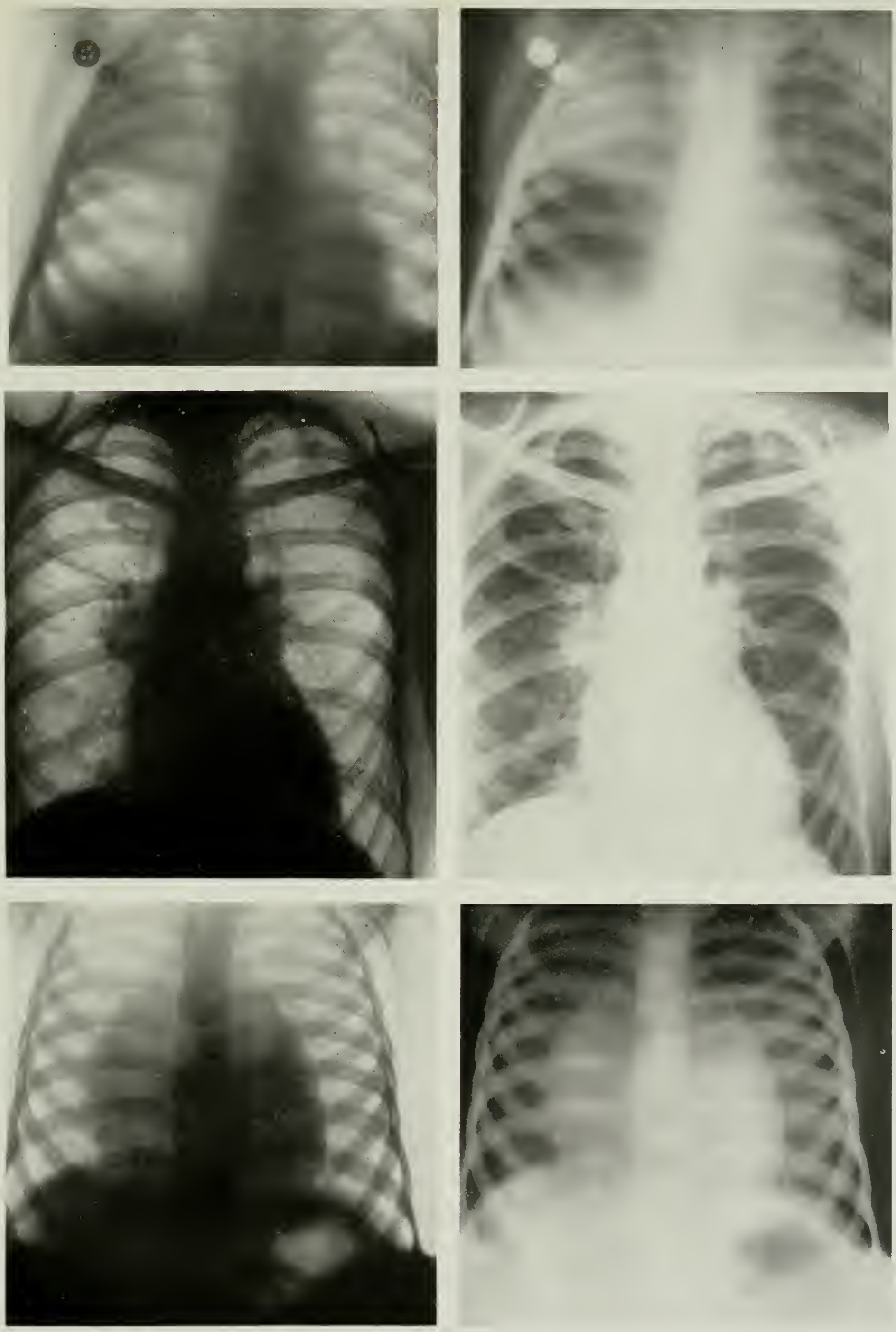
Fig. 255.—Diagram to illustrate the appearance of thorax in semi-lateral position.

In the case of aortic aneurisms there will be seen shadows of varying density and size, projecting to the right or left of the central shadow, limited by rounded, sharply defined, and often pulsating borders. The direction which the bulge takes may give an indication of the position of the aneurism. A shadow projecting to the right and lying nearer to the front than the back indicates an aneurism of the ascending aorta, whereas a similar bulge to the left, and lying nearer the back than the front, indicates the presence of an aneurism of the descending aorta.

There are other methods of detecting the position and origin of an aortic aneurism:

(1) The tube may be moved from side to side or up and down.

(2) The patient may be rotated, and observations made of the change



a

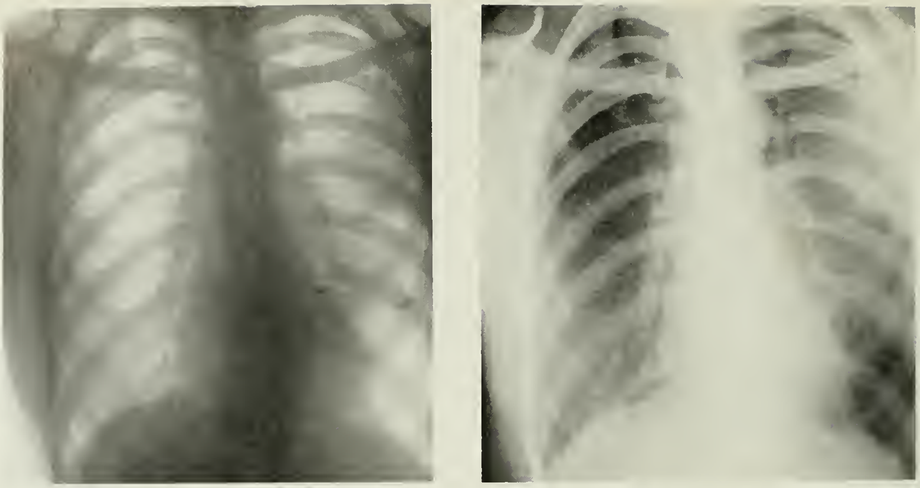
b

c

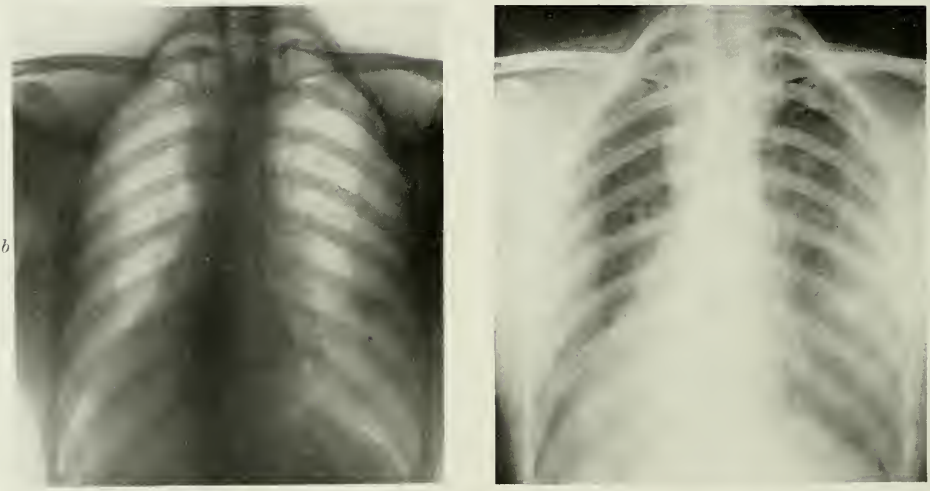
PLATE LVII.—CHESTS SHOWING CHANGES IN HEART AND LUNGS.

a, Lobar pneumonia, localised to right upper lobe.
b, Secondary carcinoma of mediastinum spreading out into lung substance.
c, Greatly enlarged heart. Hypertrophy and hydropericardium.

a



b



c

PLATE LVIII.—THORAX SHOWING CHRONIC PLEURISY WITH BI-LATERAL EFFUSION.

(*From the same patient at several months' interval.*)

a, Thorax taken with plate on anterior aspect.
b, Plate on posterior aspect. Shading at bases indicates involvement of pleura by carcinoma.
c, Double pleural effusion.
The patient had been operated upon for carcinoma of the breast, and died with signs of secondary deposits in the lungs and pleura.

in shape of the shadows as the patient moves. The size of the shadow as seen in the ordinary methods of examination is misleading, the distortion caused by the nearness of the tube to the patient making the resulting

FIG. 256.—Diagrams to illustrate points of difference between dilated aorta and aneurisms (after Holzknecht).

1. Normal heart and aorta seen from the front.
2. Normal heart and aorta, lateral oblique view.
3. Normal aorta and antero-posterior position.
4. Normal aorta in lateral position.

5 and 6. Appearances seen in dilated aorta. Antero-posterior and lateral positions.
7 and 8. The appearance seen in aneurism. Antero-posterior and lateral positions.
9 and 10. A small aneurism arising from the under aspect of the arch.

shadows appear larger than they really are, the distortion being equal on all the structures recorded on the plate.

If the exact size of the organs is required, then we must use orthodiagraphy or tele-röntgenography. The former consists of an accurate drawing of the size of the heart and aorta on a paper in front of or behind the patient, a somewhat complicated mechanical device being necessary. This method is very rarely used in this country, though it has been extensively used by Continental workers, notably by Groedal of Mannheim, who gives many interesting diagrams of typical cardiac conditions. He differentiates between the cardiac outlines in various forms of cardiac disorder, such as mitral stenosis, aortic insufficiency.

Tele-röntgenography consists of making pictures at a considerable distance from the anti-cathode of the tube. When the distance is from 6 to 6½ feet the size of the shadows practically approaches the actual size of the organs. To obtain good pictures the exposure must be rapid, and this can be obtained only when a powerful installation is used.

The presence of pulsation must be carefully looked for. When found it is often difficult to determine whether it is caused by the pulsation of the aorta, or is the normal, or that communicated through a tumour in the mediastinum.

The most important position for the determination of aneurism of the aorta is the *right lateral oblique*, first described by Holzknecht in 1901. By its means we are able to demonstrate nearly all aneurisms; but the great value of the method lies in the demonstration of quite small aneurisms, which in the other positions are masked by the central opacity. To assume this position the patient stands with his back to the tube and his face to the screen or plate, and turns half round towards his right side, holding his arms above his head.

The important points to determine and to differentiate must be borne in mind. A dilated aorta will simulate an aneurism on the screen. It pulsates, and there is a widening of the aortic shadow. The normal aorta in a number of cases shows at the arch a distinct bulge to the left, which must not be mistaken for an aneurism.

The Examination of the Heart

For practically all of the routine examination of the heart it will be well to use a standard distance in order that the distortion, which is unavoidable at all distances within the 2-metre limit, may be uniform in all plates examined. When this is so the distortion need not seriously enter into the matter, since it is the same in all cases.

A convenient distance between the plate and the anti-cathode of the tube would be 70 centimetres (28 inches). This might be designated the standard distance for all thoracic and abdominal work. At this distance the distortion of any structure, or portion of a structure, or organ in the centre line is comparatively slight. The distortion of the contour of the organ towards the periphery increases as the rays leave the central axis. Köhler has shown that the displacement of the image of the left border of the heart is greater by 1 centimetre with a focus distance of 70 centimetres, than with a focus distance of 2 metres. At the latter distance the distortion is practically negligible for all parts of the organ. Seventy centimetres is therefore a good distance at which to place the patient. A fixed point on the plate-holder can be arranged so that the distance is readily obtained.

At the distance of 70 centimetres the diaphragm of the tube-box is arranged so that the rays will completely cover a 15 × 12 plate. The tube should be centred over the mid-point of the plate, and for thoracic work the point on the patient over which the central ray is fixed would be the xiphoid cartilage in front and a line between the angles of scapulæ behind.

When it is possible to obtain full exposures of the thorax at a distance of 2 metres, then tele-röntgenography of the thorax is of decided advantage in cardiac work, because the heart shadow is shown without any distortion. In making exposures at intervals of time this is of great service, enabling us to dispense with the orthodiagraph.

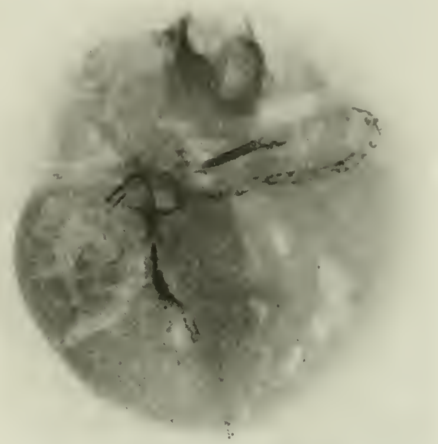


FIG. 256*a*.—Radiograph of heart showing atheroma of coronary arteries. Post-mortem specimen.

The repeated examination of cardiac cases will enable the radiologist to record the varying condition of the heart at intervals.

The employment of radiography in heart work is on the increase. The screen examination is of the greatest possible value, but the radiograph, to be of any service, must be taken with the shortest possible exposure. In the $\frac{1}{100}$ of a second it is possible to show the shape of the heart in inspiration and expiration, and even in the stages of a complete cardiac cycle when the plates can be changed rapidly.

Further valuable work has been initiated by Dr. A. W. Crane,[1] who has produced radiographic tracings of the movements of the heart, which are of value when compared with the tracings taken with the electrocardiograph and the sphygmograph. These are obtained by the use of a special plate-changing mechanism, which slowly moves the plate over a horizontal slit diaphragm. The tube is active during a considerable period of time, while the plate moves slowly over the slit in the diaphragm. The appearance of a plate so exposed is extremely instructive and interesting, and serves to indicate yet another useful field for radiographic research.

[1] "Röntgenology of the Heart" (*American Journal of Röntgenology*, Nov. 1916).

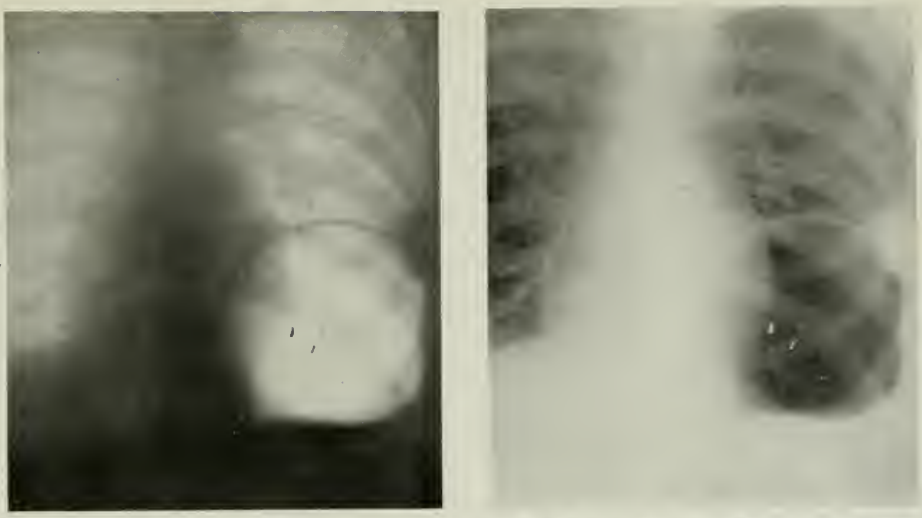
THE X-RAY EXAMINATION OF THE ALIMENTARY SYSTEM

The routine examination of the alimentary system with the aid of X-rays is one of growing importance to the radiologist. The value of this diagnostic agent in practical medicine and surgery is rapidly becoming apparent, but only by the hearty co-operation of the radiologist, the practising surgeon, and the physician can we secure the full benefit of its use. The radioscopic and radiographic evidence is always obtainable, but what is wanted is the accurate interpretation of this evidence. This can only be obtained as the result of accumulated experience. What is becoming very evident is the fact that in radiography we have an agent which enables us to distinguish pathological processes in the living subject at an earlier stage than those found in the post-mortem room. This evidence, coupled with clinical experience, should enable us to recognise at a very early stage pathological processes which we could only guess at before. The value of this advance must be apparent to all.

In order to obtain the fullest value from a consideration of the X-ray examination of the alimentary tract, the investigator must be thoroughly familiar with the technique employed. It is also essential that both the radiologist and the surgeon or physician should have a practical knowledge of the appearances presented in the perfectly normal subject. A knowledge of the pathological conditions likely to be met with is a *sine qua non* in this work, and, moreover, the operator should be familiar with the appearances shown in any departures from the normal when they are subjected to an X-ray examination. The technique of this method has developed rapidly with the improvements in apparatus, and, as experience accumulates, the value of an individual operator increases proportionately with the number of cases he is called upon to examine. Greater accuracy in diagnosis must follow upon the accumulation of experience, and when it is possible to standardise methods the value of X-ray examination will be correspondingly greater.

A doubtful case should be sent for Röntgen examination, with a careful note of the history and details of the physical signs and symptoms and of any laboratory tests that are available. These may give a clue as to the method of examination most likely to be useful in elucidating some doubtful point in the diagnosis. The aim of the radiologist should be to interpret the condition from his particular point of view, and from all these preliminary

a



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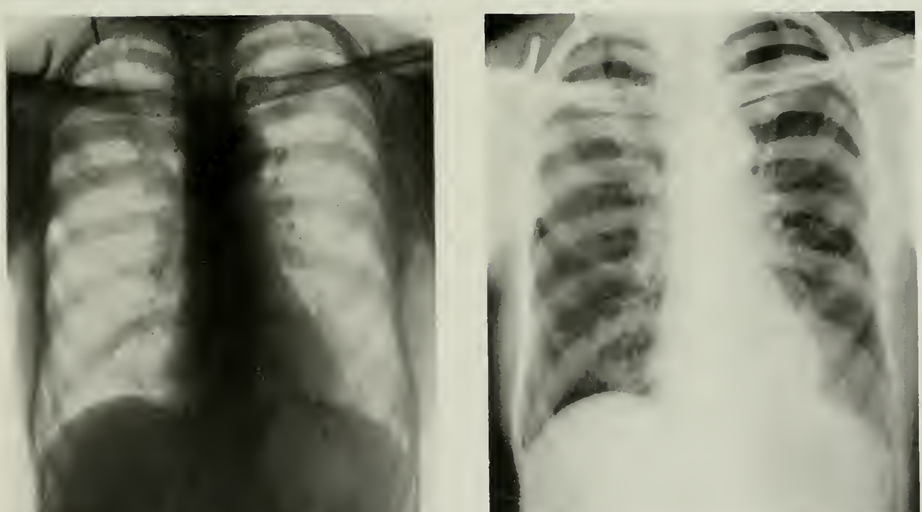


PLATE LIX.—RADIOGRAMS SHOWING CHANGES IN POSITION OF DIAPHRAGM AND CALCAREOUS GLANDS.

a, The arch of the diaphragm on the left side is high, the clear area is caused by gas in a distended stomach. Note fluid level at the lower limit of the clear area.

b, Extensive distribution of calcareous glands in thorax, axillæ, and cervical regions. Healed tuberculosis of many years' standing.

c, Calcified glands at roots of both lungs. Healed tuberculosis.

a

b

c

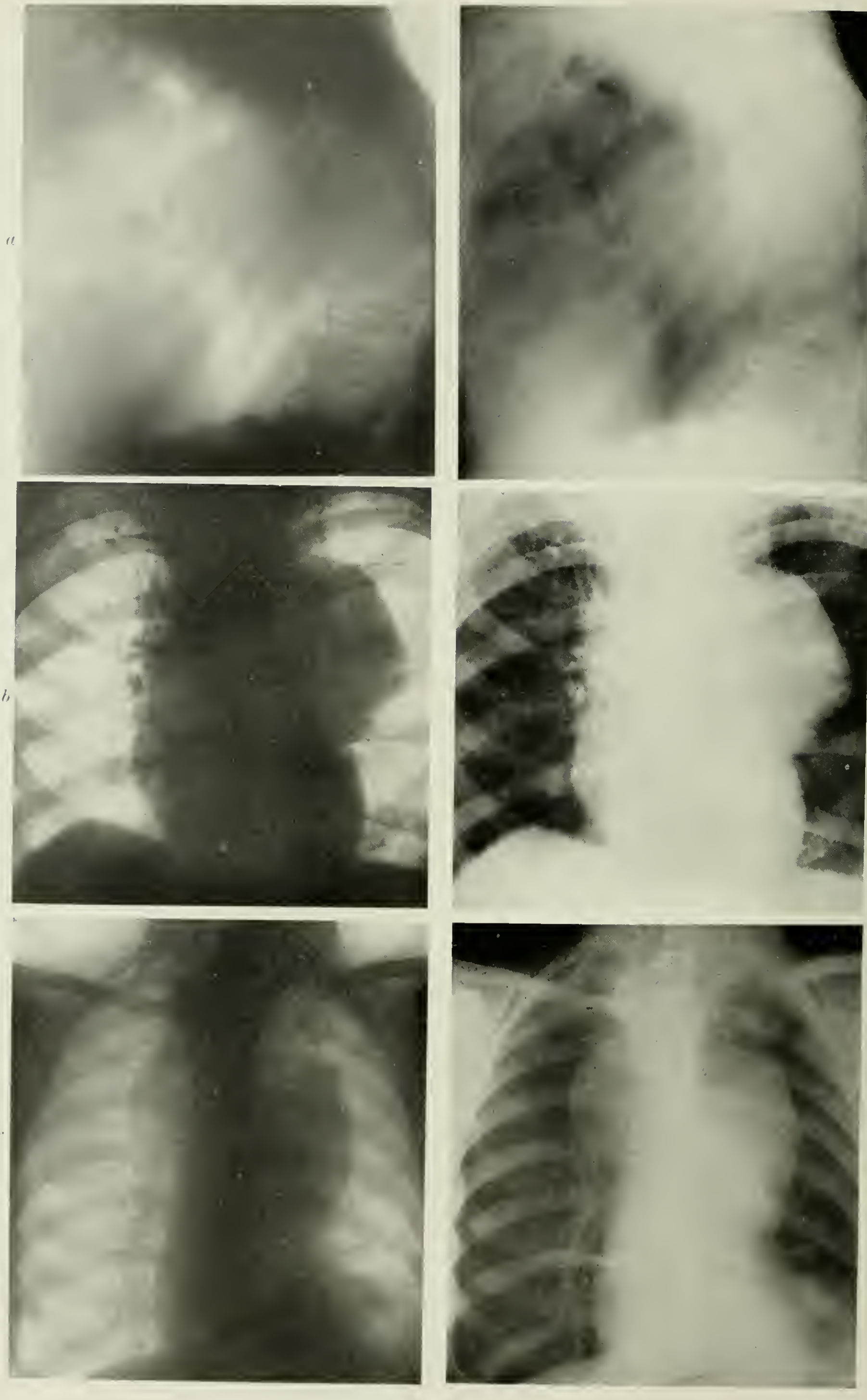


PLATE LX.—CHESTS SHOWING ANEURISM AND NEW GROWTH.

a. Aneurism of descending aorta, lateral.
b. Same case, antero-posterior position.
c, Secondary growth in mediastinum, simulating aneurism.

data he is often able to determine on which part of the examination to lay the most stress.

The diagnosis in many of the cases which come for Röntgen examination is already determined with a fair degree of accuracy by the older methods. The radiologist confirms and establishes the diagnosis and frequently assists the surgeon in the determination of the extent of the operation, or gives valuable aid in locating the situation of the lesion.

For example, the incidence of hour-glass stomach is much greater than was formerly supposed, and in this statement we exclude the large number of cases where the hour-glass condition is spasmodic in character ; true hour-glass contraction is more common than was supposed. The demonstration of an hour-glass condition is very helpful to the surgeon in determining the nature of an operation. In a number of cases the radiologist is able to say that a definite degree of stenosis of the pylorus is present, and this fact may decide the surgeon to operate. In other cases it is possible to show the extent of the dilatation of the stomach, and again encourage the operator to interfere. So much can be ascertained by a thorough examination with the aid of the opaque meal that a lengthy description of this is necessary.

Methods of Examination.—(1) *Radioscopy* by means of the fluorescent screen. (2) *Radiography* by the action of X-rays upon photographic plates, a comparison being made of plates taken at intervals. Both methods are extremely useful, and neither can be dispensed with if a thorough examination and record of observations are necessary for the completion of the investigation of any particular case. By these methods many observations of value may be made. The localisation of a foreign body becomes easy, while strictures in the œsophagus, and diseases of the stomach and bowels are now daily subjects for Röntgen examination.

The Examination of the Œsophagus

The presence of a number of diseased conditions, abnormalities, and the pressure effects of other thoracic conditions on the œsophagus can readily be shown by the use of a quantity of bismuth emulsion and subsequent examination by screen and plates. The substances most commonly used are bismuth or barium salts in the shape of (1) *cachet* ; (2) *emulsion* ; (3) *in food*, e.g. *sugar of milk*, *bread-crumbs*, *porridge*, *etc.* (See page 310.)

The œsophagus may be examined in five positions, namely :

(1) *Antero-posterior*, when shadows of tumours may sometimes be shown.

(2) *Postero-anterior.*

(3) *The right antero-lateral, right oblique.*—This is an important position. The patient stands upright with the tube behind, and the fluorescent screen placed in front. The right side of the thorax is placed against the plate or screen, the left side being directed obliquely backwards and to the left. The central ray passes through the thorax obliquely from left to right (see Fig. 257). A little manipulation of the patient may be necessary in order to get the best view of the parts. The patient is adjusted so that the position of the spine relative to the heart and aorta gives

the maximum clear space between the two, this clear space containing the œsophagus. A little practice enables the operator to get the best position. The patient is told to swallow some opaque food, and the operator keeps a careful watch for its passage down the œsophagus, this being indicated by a dark rapidly moving shadow passing down the œsophagus to enter the stomach. Any delay in transit should be carefully noted. By this method of examination it is possible accurately to locate stricture of the œsophagus or obstruction at the cardiac end of the stomach. Foreign bodies may readily be detected in the œsophagus and accurately located.

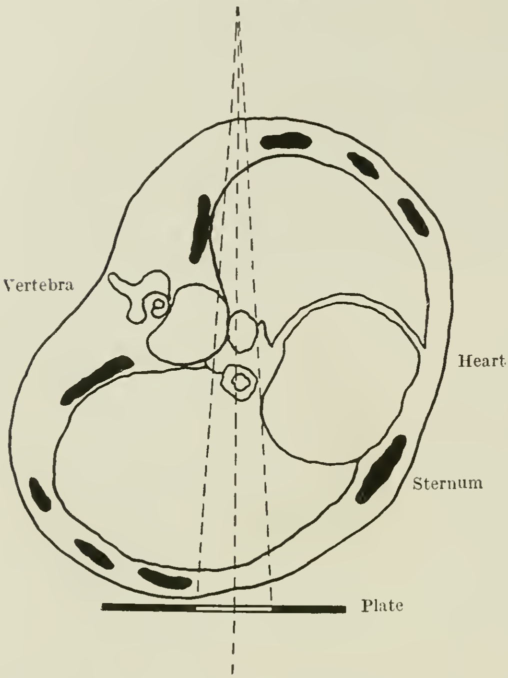


Fig. 257.—Diagram to show the position for lateral oblique examination of the thorax, and the path of the rays from tube to plate.

The other useful positions are (4) *left antero-lateral, left oblique*;[1] (5) *lateral.*

Radioscopy and radiography may both be employed in the examination of the œsophagus. They are valuable aids in the diagnosis of many diseases of the œsophagus, and are of the greatest help to the clinician when combined with the examination with the œsophagoscope. The technique is similar to that described in the routine examination of the thorax, the lateral and lateral oblique positions being the most useful.

A brief consideration of the departures from the normal met with in the œsophagus will be necessary, and where possible the method of demonstration and appearances under X-rays will be referred to.

Anomalies of the Œsophagus

The chief congenital conditions met with are: (1) Imperforate Œsophagus; (2) Stenosis; (3) Œsophago-tracheal Fistula; and (4) Pharyngeal Pouches.

[1] The author has found a simple method of obtaining the best position for the examination of the œsophagus. The patient stands with his back and the left side of the thorax toward the fluorescent screen; the left hand is pressed against the board in front of the tube-box while the right hand is brought round to grasp the lower edge of the fluorescent screen. The patient can readily be adjusted to the required angle by rotating the pelvis, and when this is obtained he is instructed to press against the board with the left hand and to pull with the right hand. This secures steadiness during exposure. A good lateral oblique view of the spine and of the œsophagus is almost invariably obtained with this position.

Imperforate Œsophagus is met with in the newly born infant, and will not often require X-ray examination. Should there be a doubt as to the nature of the condition a small quantity of bismuth in milk could be given to the child, and the thorax and neck screened. At such an early age this would be preferable to œsophagoscopy, and would be quite as useful for diagnostic purposes.

Congenital Œsophago-tracheal Fistula is more frequently met with than imperforate œsophagus, and is due to developmental errors. The condition is likely to be discovered early in life, though it may happen that it exists without a complete opening on the surface. The leakage of food through the fistula will give an indication of the condition.

FIG. 258.—The appearances seen on the fluorescent screen after the patient has taken bismuth food are shown diagrammatically. The shadows represent the passage of a number of mouthfuls of food down the œsophagus; when a large quantity is swallowed in successive acts of deglutition, a continuous line of dark shadow is seen. This may be seen to vary in diameter, corresponding with the contractile movements of the œsophagus.

FIG. 259.—Diagrammatic representation of the semi-lateral view of thorax.

When there is no marked narrowing of the channel into the œsophagus, food will pass down, and the patient may live for some time. In such a case the condition may require to be diagnosed from fistula, the result of ulceration due to the presence of a foreign body.

Congenital Stricture of the Œsophagus.—This condition in its minor manifestations may be more common than is generally supposed, because, when a minor condition is present there will only be a minor degree of inconvenience, which may not receive more than a slight degree of attention.

In the more marked conditions the diagnosis may be cleared up by a radioscopic examination, during which the food may be seen passing down the œsophagus, and marked arrest of its passage may be noted. A consideration of the history will aid in distinguishing the congenital from the acquired stenosis of the œsophagus.

Inflammation and *Ulceration of the Œsophagus* may cause difficulty in swallowing, which may suggest a more serious lesion, but time should always be allowed to elapse and the patient be examined at a later date before arriving at such a diagnosis. Both methods (*i.e.* radioscopy and radiography) should always be employed in these cases.

Compression Stenosis of the Œsophagus.—This may be the result of disease in the vicinity of the œsophagus. The most frequent causes are :

(1) Lesions of the thyroid gland which cause enlargement; (2) glandular enlargements in the cervical region; (3) malignant disease; (4) aneurism; (5) disease of the heart, attended by enlargement of the organ; (6) tumours of the spine; (7) lordosis; (8) traumatism; (9) cardiospasm. Tumours of the mediastinum may also cause compression effects upon the œsophagus.

Aneurism will give rise to compression effects at the corresponding level of the œsophagus. It may often be extremely difficult to distinguish between this mechanical stenosis and an early stage of malignant disease of the œsophagus. Repeated examinations may be necessary before the distinguishing features show themselves. In all suspected cases the aortic area should be carefully screened for signs of pulsation and dilatation.

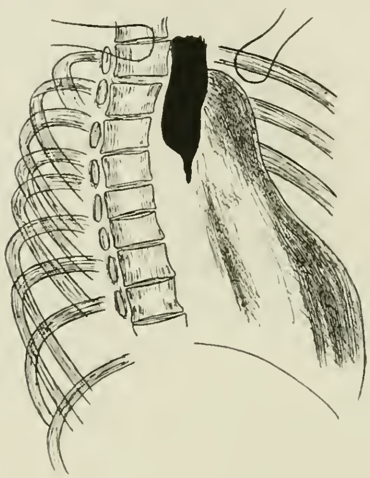


FIG. 260.—Diagram to illustrate the appearance seen in a semi-lateral view of the thorax. The dark shadow at the top is caused by bismuth food in a dilated œsophagus. The point of stricture is seen at the lower extremity of the dark shadow.

FIG. 261.—Spasmodic stricture of the œsophagus, simulating true stenosis.

Neurosis may play an important part in the history of an œsophageal obstruction. In such cases it is often extremely difficult to establish a diagnosis. Care in the examination and distraction of the attention of the patient may induce a condition in which the œsophagus acts normally at the time of inspection. In doubtful cases the administration of anti-spasmodics and sedatives may have the desired effect.

Figure 261 illustrates a condition of œsophagus which is strongly indicative of a stricture due to malignant disease. A second examination after four days' interval demonstrated that there was no actual stricture. The effect shown was obviously due to reflex spasm.

Pharyngeal Pouch.—Dr. N. S. Finzi, in an interesting paper read before the Electro-therapeutic Section of the Royal Society of Medicine,[1]

[1] *Transactions of the Roy. Soc. of Medicine: Electro-therapeutic Section*, 1917.

calls attention to the importance of distinguishing pharyngeal pouches from stricture of the œsophagus. He states that this condition is pharyngeal in origin and not, as it is so often described, œsophageal.

The method recommended for the successful demonstration of the condition is to administer a thick paste of oxychloride of bismuth, in preference to the barium sulphate. The bismuth forms a more adhesive mixture than the latter, and consequently clings more readily to the wall of the œsophagus. The paste is made of such a consistency that when heaped up it has practically no tendency to flow back to a level.

Finzi describes a number of cases which are extremely interesting when compared with cases of undoubted stricture of the œsophagus. He gives the cardinal difference between a pouch and any form of stricture as follows : The pouch must empty from its upper end, while the stricture does so from its lower end. A carcinomatous œsophagus shows a conical shape at the point of stricture, and has not the bulbous appearance seen in the case of a pouch. A case of carcinoma may, however, simulate a pouch.

Holzknecht also calls attention to a new differential sign in the diagnosis of diverticula of the œsophagus. This appearance is usually present in small newly formed pockets, but it may be absent in larger diverticula. In the cup-like dilatation due to carcinoma, the bismuth is seen to trickle slowly past the shadow. In delay due to a diverticulum the food trickling past is of as large a calibre below the diverticulum as above it.

The Diagnosis of Diseases of the Œsophagus

It is not intended to enter fully into this interesting subject, but a description of the technique of the examination and a short review of the diseases of this structure likely to complicate a diagnosis are necessary.

The examination of the œsophagus is included in the survey of the thorax for diseases of other organs, and in some instances the lesion may be accurately located in this structure by the ordinary examination. This statement applies particularly to marked dilatation, hypertrophy with or without dilatation, in rare instances new growth, and pouches when they contain food and foreign bodies. To exclude the œsophagus as a cause of obscure thoracic symptoms, it is necessary to conduct the examination on the lines of the special technique employed in the examination of the alimentary system. The patient is examined in the upright position in front of the X-ray tube, and the screen is placed in front of the patient. A short scrutiny of the thorax in this position enables us to exclude those conditions which show when no opaque food is given, especially if the patient is examined in the lateral position. The opaque substance may then be administered in one or other of these forms :

(1) Bismuth or barium salts in a cachet. This method has been discarded as unreliable. A cachet may remain in a normal œsophagus for quite an appreciable time.

(2) Bismuth or barium in an emulsion. This is also unsatisfactory.

for the medium passes too readily down the œsophagus, and an early stricture may readily be overlooked. Bismuth and oxychloride in water to form a thick paste is recommended by Finzi.

(3) Bismuth or barium salts in a mixture consisting of bread-crumbs and milk. This, if of the right consistency, is the best of all,[1] for it enables us to watch the passage down the normal œsophagus, and if the patient swallows steadily and continuously for a few moments the character of the œsophageal wave can be studied from the pharynx to the stomach. In diseases such as stricture, the food is held up for appreciable intervals of time.

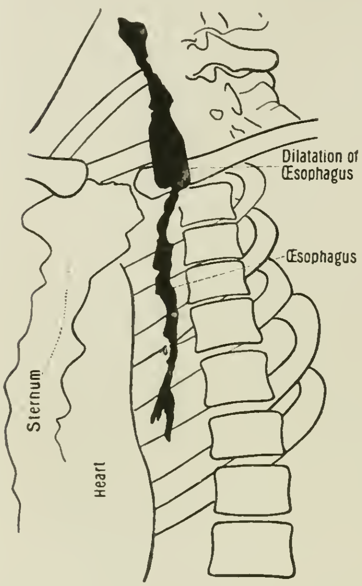


FIG. 262.—Long narrow stricture of the œsophagus, with dilatation of the upper part.

A word of caution is necessary here. Absence of delay alone in the passage of food into the stomach does not justify the dismissal of an early stricture or disease. An early carcinoma may not lead to any constriction, and consequently there is no delay in the transit of the food.

The demonstration of early obstruction is one of the most valuable of the many uses of radiography, and depends upon three factors: (1) The consistency of the medium employed; (2) the degree of stricture present; and (3) the peristaltic activity of the œsophagus above the stricture.

The X-ray method of examination of the œsophagus has this advantage over other methods, that it sometimes reveals the presence of other conditions which may contra-indicate the employment of instruments which require the employment of force during the examination,—for example, aneurism of the aorta, tumour of and around the œsophagus, or the existence of large new growths near the œsophagus.

The diseases most likely to cause difficulty are: (1) Simple stricture with dilatation of the œsophagus above; (2) malignant disease with or without dilatation; (3) simple dilatation, cardiospasm.

Œsophageal Obstruction.—The causes of œsophageal obstruction are numerous, and may be divided into several groups:

(1) *Obstruction due to pressure from without.*—This is usually due to diseases of other organs, such as aneurism; new growth of the mediastinum, lungs, pleura; tumour of the spine; enlarged mediastinal glands; mediastinal abscess.

[1] The consistency of the opaque food is important. It should not be too thin, because in an early stricture it might pass down freely and so lead to error; on the other hand, if it is too thick it might cause appreciable delay in a normal œsophagus. For a thorough examination of the organ it may be well to use two preparations, commencing with the thin one, and, if no delay is observed with this, finishing with the thicker preparation.

(2) *Actual obstruction of the Œsophagus.*—Due to disease in the œsophagus itself, such as new growth; ulcer of the œsophagus, with superadded spasm, leading to stricture, which may be of a temporary nature; cicatrisation following upon trauma or caustics.

(3) *Obstruction due to foreign bodies, e.g.* coins, brooches, pins, etc. These may cause more or less complete obstruction.

The recognition of an obstruction in the œsophagus is easy, but the exact determination of the cause is exceedingly difficult, and may be impossible to determine without having recourse to some of the other methods of examination.

Fig. 263.—Obstruction in œsophagus, the result of a gunshot wound.

This was found to be due to granulation tissue projecting into the lumen of the œsophagus, the result of injury to the posterior wall of same. This was treated surgically, and the patient made a good recovery.

In the *Quarterly Journal of Medicine* for July 1916, Dr. Arthur J. Hall remarks: "It has been somewhat the custom in former times to dismiss all growth of the œsophagus (with the exception of carcinoma) as mere pathological curiosities, having little or no clinical importance. The routine use of X-rays in the diagnosis of diseases of the chest and alimentary canal must make us alter our point of view in this, as in many other respects. Any pathological condition in the thorax capable of causing a shadow on the screen cannot be left out of consideration in reading the radiogram."

Figures 264 to 267 illustrate an interesting case of fibromyoma of the œsophagus.[1] The radiograms given of the thorax show a definite shadow of the enlarged œsophagus. The condition was considered to be due to a dilated œsophagus with a considerable amount of hypertrophy of its walls. The bismuth food swallowed by the patient, however, gave shadows which were rather difficult to interpret. The evidence subsequently afforded at the post-mortem examination revealed an unusual condition of fibromyoma. A comparison of the œsophagus after removal from the body with the radiograms, taken before and after the administration of the bismuth

[1] "A Case of Diffuse Fibromyoma of the Œsophagus, causing Dysphagia and Death." By Arthur J. Hall, M.D., F.R.C.P. (*Archives of Radiology*, November 1916.)

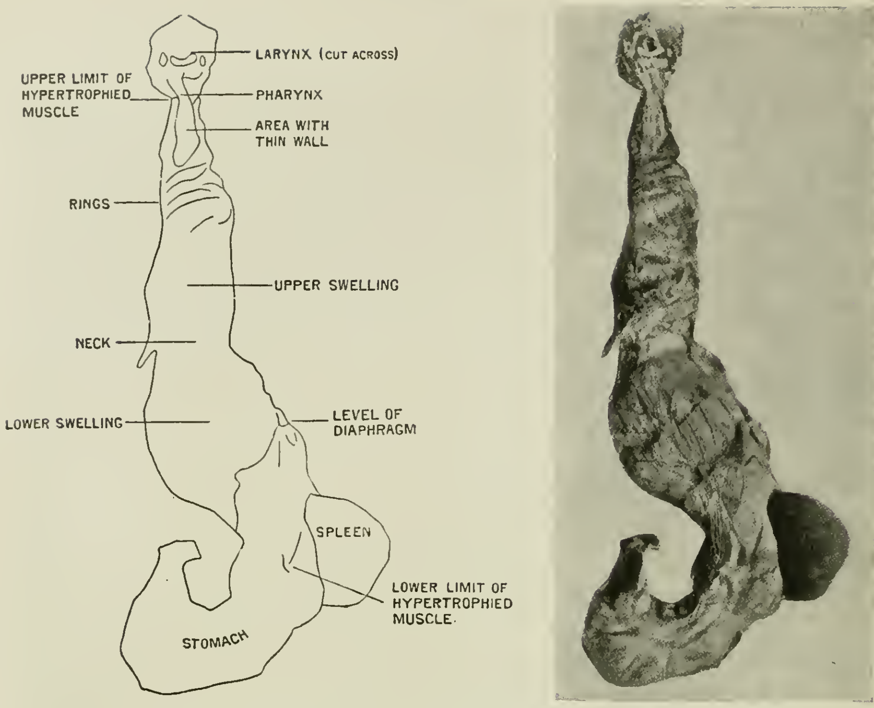


Fig. 264.—A case of diffuse fibromyoma of the œsophagus. The œsophagus and stomach after removal (with key diagram).

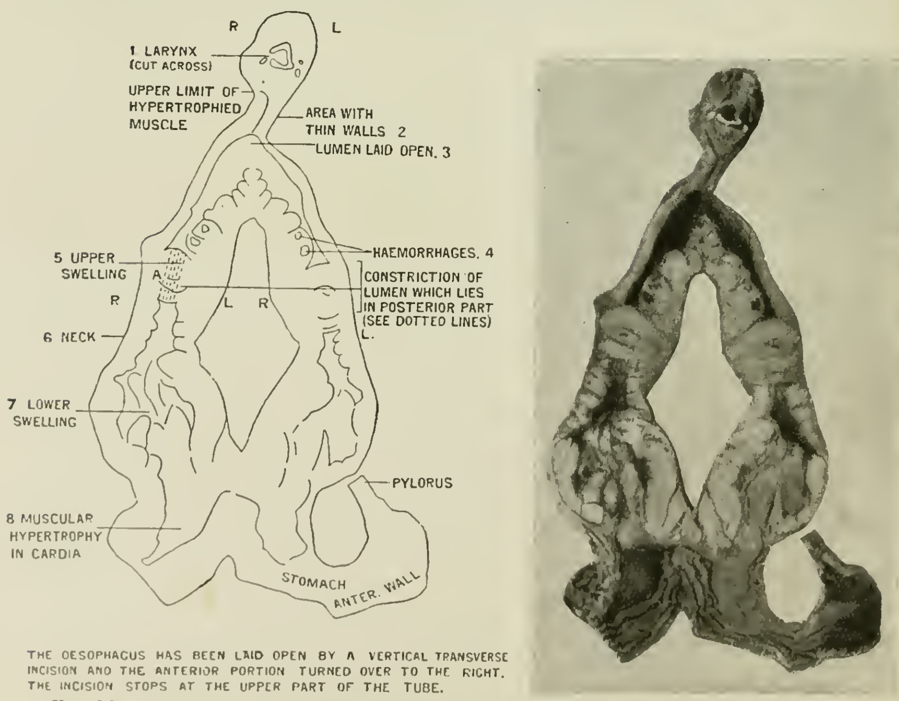


Fig. 265.—Fibromyoma of the œsophagus. Coronal section of the above (with key diagram). From *Archives of Radiology and Electrotherapy*, November 1916.

food, clearly show that the shadows which gave rise to difficulty in diagnosis were due to this pathological condition.

Cancer is probably the most frequent cause of obstruction of the œsophagus. It may appear at any part of the structure, but is most commonly met with at the middle third and near the cardiac orifice.

In the former situation the characteristic appearances are an arrest of the opaque food at a point above the stricture, a degree of dilatation of the œsophagus above the point of narrowing, and in some cases a thin faint irregular streak of opaque material below the point of stricture. This may, especially in children, have quite a tortuous outline. The degree of dilatation

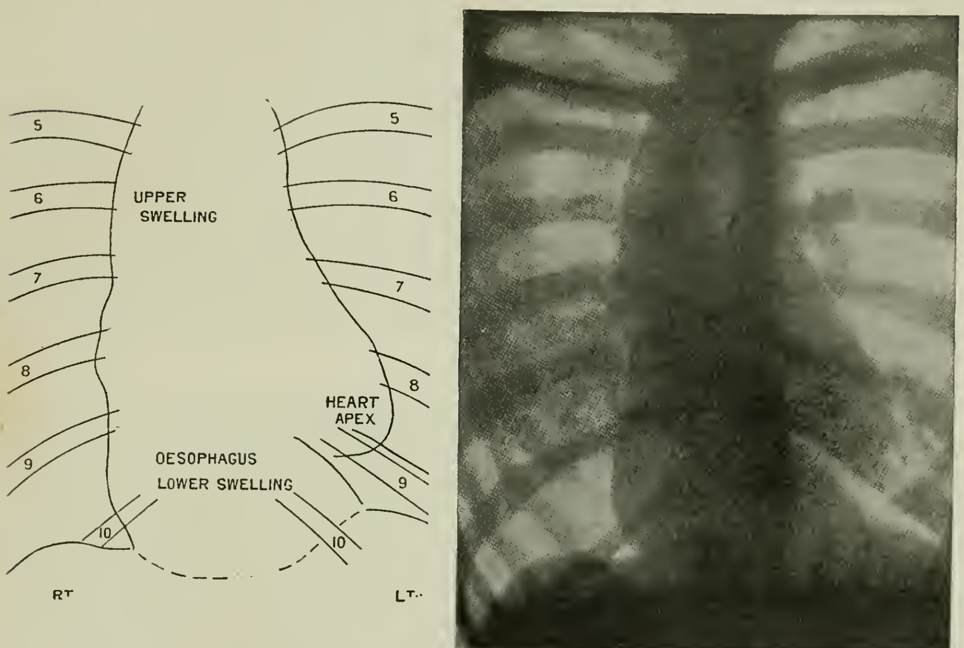


Fig. 266.—Radiogram of the thorax before the bismuth food was taken (with key diagram of same). From *Archives of Radiology and Electrotherapy*, November 1916.

in malignant disease is not as a rule so great. In simple stricture, the result of chronic ulcer or traumata, from the long-standing nature of the case, a greater degree of dilatation is likely to ensue.

In malignant stricture there is often a faint irregular shadow visible round the opaque food, invading the latter and causing a ribbon-like arrangement of the food.

The obstruction may be due to conditions within the walls of the œsophagus, namely, new growth, ulceration with spasmodic contraction, cicatrisation from ulceration or the caustic action of acids, the result of syphilitic lesions, and tuberculosis of the œsophagus.

It is often exceedingly difficult to differentiate between these conditions, but the malignant growths will later on assume proportions which will

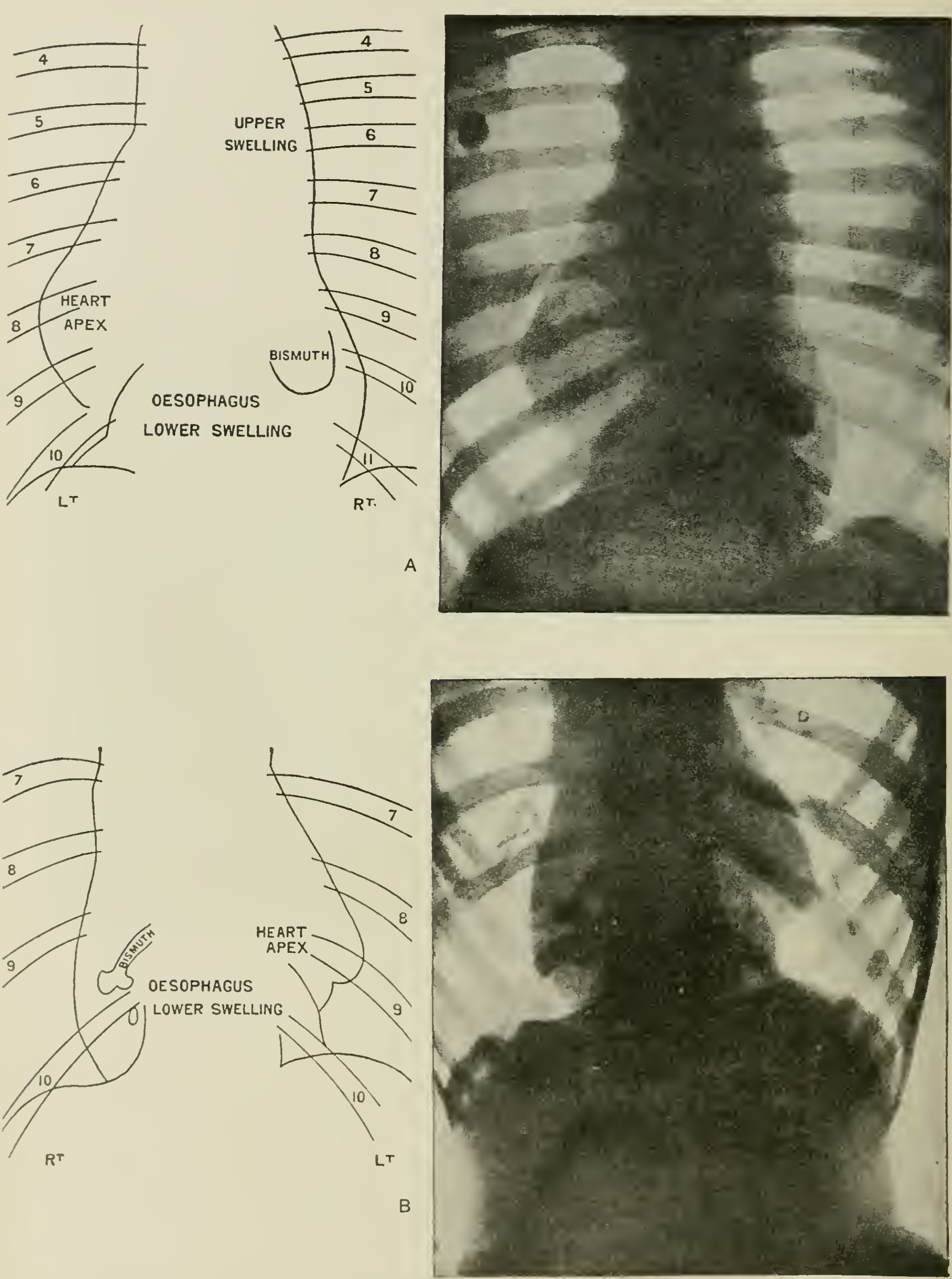


Fig. 267.—Fibromyoma of the œsophagus. Radiograms showing bismuth food in the œsophagus. *A.* Plate on posterior aspect. *B.* Plate on anterior aspect.
From *Archives of Radiology and Electrotherapy*, November 1916.

remove any doubt which may have existed. The duration of the disease in such cases is frequently much shorter, while in obstruction due to ulcer the spasmodic element predominates, and there are intervals when the patient swallows with greater ease. The ulcer may heal and lead to cicatricial changes, which later on may cause a marked obstruction, with a considerable degree of dilatation above the stricture. These cases do not exhibit a marked degree of cachexia, though wasting may follow from malnutrition.

In conditions due to cicatrisation of the œsophagus following upon the swallowing of caustics, there is generally a history of such an occurrence, and the duration of the symptoms may extend over several years.

The syphilitic cases should rarely give rise to much difficulty. A history of a previous infection, and a Wassermann test, followed by improvement under treatment, will clearly establish the diagnosis.

FIG. 268.—Malignant stricture of the œsophagus. Food seen in narrow channel; œsophagus dilated above the point of stricture, and a faint irregular streak of food below it.

A degree of obstruction due to pressure stenosis may be present in cases where there are tumours or enlarged glands in the mediastinum. These may be either simple or malignant. In the malignant cases the progress of the disease gradually increases the difficulty of swallowing. There are, however, cases where a retrogression of the growth, either as the result of treatment or a temporary diminution of size from natural causes, may lead to an improvement in deglutition. Among the less malignant cases lymphadenoma may be quoted, where, after treatment by X-rays and radium, a marked diminution in the size of the gland may lead to this temporary improvement. Similarly, in an aneurismal condition with marked dilatation, there may be a shrinkage leading to an amelioration in the symptoms. The distinction between an œsophageal obstruction due to active growth and an aneurismal condition is often very difficult, if not impossible, to establish. Other methods of investigation must be employed, and time be allowed to elapse before a final decision is arrived at. In aneurism a marked improvement may follow upon treatment, whilst in malignant cases the progress is usually steadily downwards with increasing difficulty in swallowing, and finally complete obstruction.

A malignant stricture may, in the early stages, as a result of local treatment, greatly improve, but this improvement is of a temporary nature only, the disease sooner or later reasserting itself.

Ulcers may occur with or without cicatricial changes. Very marked obstruction may result from the presence of these. Or the obstruction may arise from reflex causes, such as ulceration or new growth in the larynx. Tuberculosis of the larynx may cause a marked degree of œsophageal embarrassment.

The thoracic portion of the œsophagus may be compressed by aneurism of the aortic arch, by a mediastinal tumour originating either in the thymus or in the lymphatic glands, or by abscess in connection with the upper thoracic vertebræ. This latter condition may cause a partial or complete obstruction of the œsophagus by compressing it against the aorta or left bronchus.

Malignant stricture of the œsophagus may occur at the three points where normally it shows a slight degree of constriction : (1) At the commencement of the tube, or six inches from the incisor teeth ; (2) at the point where the œsophagus is crossed by the left bronchus, or ten inches from the incisor teeth ; (3) at the distal end of the tube, or fifteen inches from the incisor teeth.

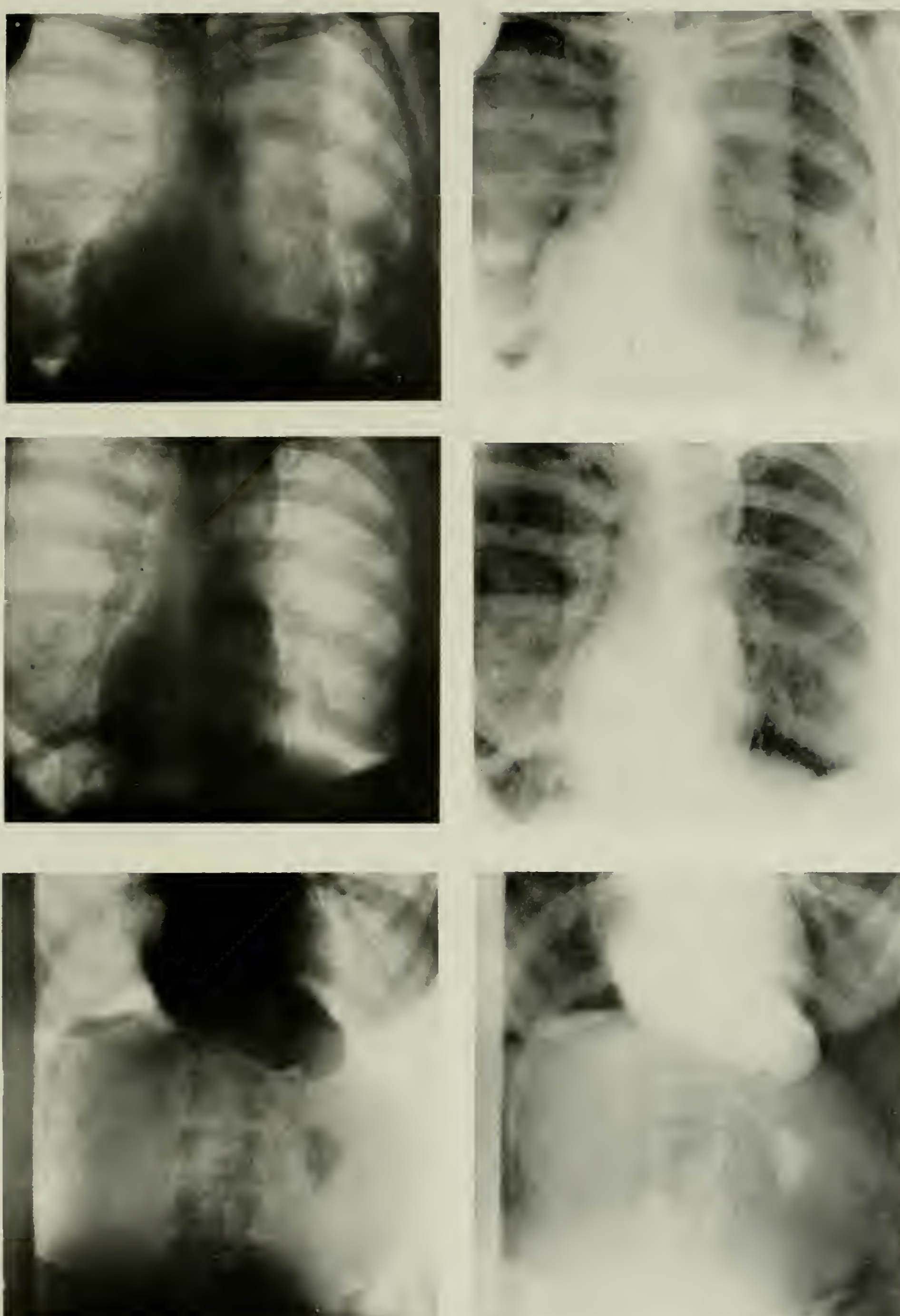
As a rule the stage of hypertrophy on the proximal side of an obstruction is followed by a stage of dilatation. There are in reality three stages in the course of an obstruction of the œsophagus in simple or malignant stricture.

(1) That of difficulty in swallowing. This may be present for a considerable time before any obstruction is found. In this stage the differential diagnosis may be very difficult, and the distinction between it and obstruction due to functional conditions has to be made.

A radiographic examination in the very early stage of a malignant stricture is of the greatest possible value, as it aids so much in suggesting the appropriate treatment. It is also useful in a negative sense in the hysterical condition, for it is often only necessary to convince patients suffering from this condition that there is no evidence of malignant disease to effect a speedy and often a permanent cure.

(2) The second stage, that of a degree of constriction with partial obstruction, is accompanied by some hypertrophy on the proximal side, which may for a long time maintain a condition of equilibrium. At this stage there may be no sign of emaciation.

(3) The third stage of more marked or complete obstruction is frequently accompanied by considerable dilatation of the œsophagus. Here the distinction has to be drawn between a simple and a malignant stricture. In the former condition the history is generally longer, extending over many years in some cases, the longest the writer has come across being twenty years. This in itself excludes malignant disease. In non-malignant dilatation the œsophagus may become dilated to an enormous degree. The central



a

b

c

PLATE LXI.—CHEST SHOWING DILATATION OF ŒSOPHAGUS.

a, Œsophagus dilated and filled with food.
b, Œsophagus empty after an interval of 3 days, showing irregular shading in mediastinum.
c, Lower portion of dilated œsophagus containing bismuth food ; point of stricture is seen, and food which has passed into the stomach.

area of the chest is occupied by an elongated shadow, extending down to the diaphragm and terminating high up in the superior mediastinum. If fully distended by food, it is clearly seen on the fluorescent screen, and on the right side an occasional feeble peristaltic wave can be detected. This is quite distinct from the pulsation of an aneurism of the descending aorta. It has a large wave-like motion, which is quite unmistakable for any other type of movement. The enlargement is much more pronounced on the right side of the thorax than on the left. There is an anatomical explanation of this phenomenon. This type of case has been described as œsophagospasm, or cardiospasm, on account of the spasmodic character it assumes.

FIG. 269.—Obstruction near the cardiac end of the œsophagus.

Note the marked dilatation of the œsophagus, terminating in a funnel-shaped channel. This was probably a case of cardiospasm.

Food may be retained in the œsophagus for several days, then suddenly the spasmodic condition relaxes and the œsophagus empties into the stomach, or, as more frequently happens, the patient empties the dilated viscus by vomiting.

The bismuth or opaque food should always be used in the examination of these cases. Food can be seen to fill the whole of the dilated œsophagus, and at the cardiac end a peak-like formation of the bismuth food indicates the seat of the obstruction. The degree of dilatation is easily demonstrated if the whole œsophagus is filled with the food. Care should be taken in these cases not to make the mixture too thick, in case the patient may have difficulty in getting rid of the food.

In doubtful cases an œsophageal tube filled with opaque material should be passed down the œsophagus, and the direction it takes watched on the screen. In a case of cardiospasm it may be seen to turn upwards at the cardiac opening, missing the opening altogether.

These cases are occasionally mistaken clinically for malignant disease of the stomach. Figure 270 illustrates a condition of this kind where the patient had for sixteen years been unable to take anything more solid than Benger's food and liquids. The œsophagus was greatly dilated. On two occasions the stomach was apparently " washed out " and free hydrochloric acid found to be absent. Radiographic examination revealed the true condition. The œsophagus was dilated from below through a laparotomy

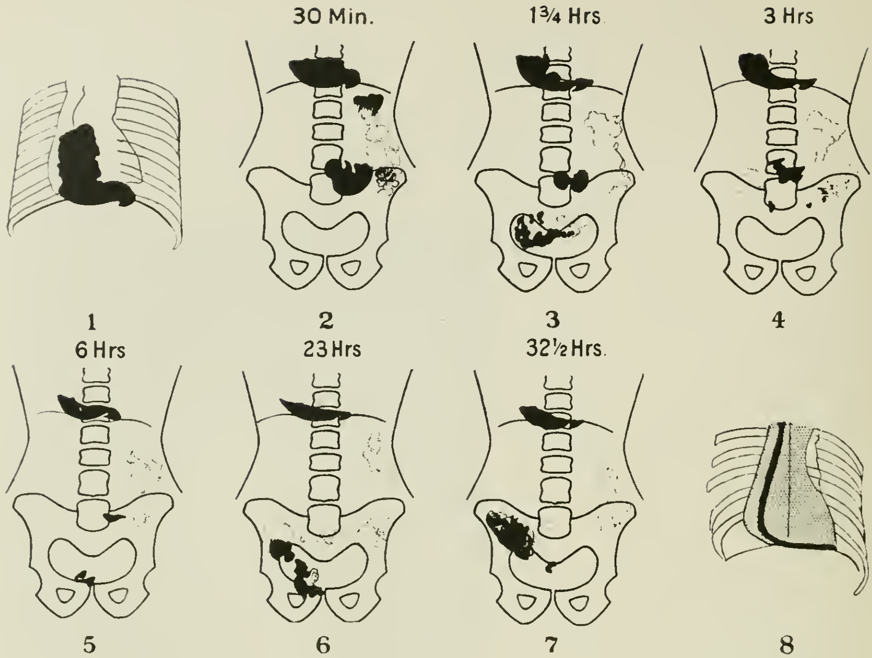


Fig. 270.—Drawings from radiograms in a case of chronic dilatation of the œsophagus. Recorded by Dr. Wakeley.

1. Dilated œsophagus immediately after the opaque meal was taken. 2 to 7 taken at intervals as marked, showing the rate at which the food passed into the stomach. 8. Opaque tube in dilated œsophagus—some days later.

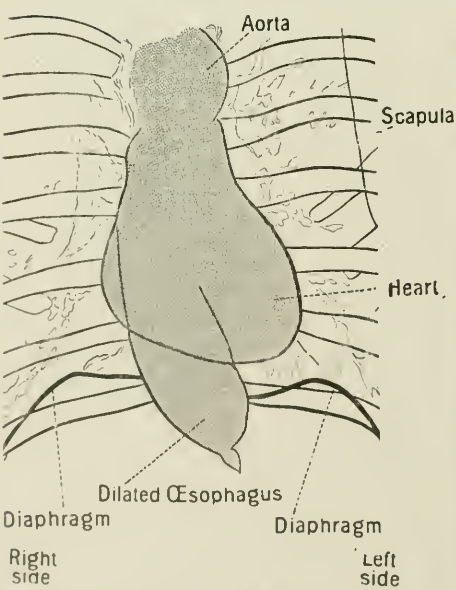


Fig. 271.—Drawing from a negative of an antero-posterior view of a case of cardiospasm.

Fig. 272.—Radiogram from the same case taken in the left antero-lateral, left oblique position described on p. 306 (footnote).

opening, after which the patient rapidly regained the lost weight and was again able to swallow solids. The clinical side of such cases is extremely interesting. In the early and middle stages there is no marked loss of weight, and the patient may appear to be in a fairly normal state of health. In the third and sometimes fatal stage the patient presents all the appearance of malnutrition. He is thin to the point of emaciation, is feeble, and looks toxic ; he is, in fact, absorbing toxins from the fermentative changes taking place in the œsophageal contents.

Dulness can be made out on either side of the sternum on percussion. The enlargement is more marked to the right side. The abdominal walls are collapsed. The case may therefore readily be mistaken for one of tumour at the cardiac end or in the stomach. Radiographic examination will reveal the true condition, and lead to some improvement in the health of the patient if treatment is possible.

Cardiospasm (Hiatal Œsophagismus).—This interesting condition must not be overlooked in the routine examination of the œsophagus. Lack of space forbids a lengthy description, but the condition is readily recognised, even when no opaque food has been given, if the œsophagus contains food. An interesting diagnostic sign in such a condition is a slow rhythmical contraction wave passing along the right side of the dilated œsophagus. It is well to examine such cases on more than one occasion in order to obtain definite evidence in favour or otherwise of a diagnosis of cardiospasm.

Foreign Bodies in the Œsophagus

There are many varieties. The opaque bodies are easily recognised, but when they are not opaque considerable difficulty may be experienced in establishing a diagnosis, and a negative result at the X-ray examination does not necessarily exclude their presence.

Bythell and Barclay call attention to a method of examination which should always be employed in these cases. The patient is asked to swallow some opaque food, and the passage of this down the œsophagus is watched. A slight delay or a narrowing of the stream of opaque material at the site occupied by the foreign body will indicate the presence of such, and its position and the degree of obstruction present. All these points are of great value to the surgeon as a guide to his subsequent procedure. The obstruction may be low down in the œsophagus at the cardiac end of the stomach.

Examination of the Stomach

The examination of the stomach and intestinal canal has become one of the most important spheres of radiographic work. Its value in diagnosis is very great, but much remains to be done before a claim can be laid to expert knowledge in the interpretation of the results obtained. Even now, when the method has become general, authorities are found to hold conflicting views on the interpretation of the results. The technique followed by the observers differs in many respects, and this, no doubt, to some extent accounts for the conflicting opinions. In spite of the great difficulty in the way of correct interpretation, it is satisfactory to know that by means of X-ray examination it is possible to ascertain much about the position, size, and movements of the stomach, the process of digestion, and departures from the normal.

The importance of this method of examination in diseases of the alimentary tract can best be demonstrated by a careful survey of the technique employed and the results obtained. This embraces a full consideration of the appearances presented in the normal condition, and a summary of those presented in diseased conditions. The present-day technique is well advanced, and has been elaborated by many workers, but it is still capable of improvement. With increasing experience on the part of individual workers the possibilities are great. Time and careful work will yet demonstrate with a greater degree of certainty the value of this method.

At the meeting of the Electro-therapeutic Section of the British Medical Association, held in Liverpool in 1912, a joint discussion on the normal stomach took place with the Anatomical Section. It was almost unanimously agreed that radiography had modified the opinion held formerly as to the position of the normal stomach. Hertz describes three positions of the stomach: (1) When one-third full; (2) when half full; (3) when fully distended.

The following is quoted from Hertz's paper:

Anatomy of the Stomach

The Subdivisions of the Stomach.—The œsophagus enters the stomach very obliquely, the acute angle it forms being called the incisura cardiaca. The cardiac orifice, though not surrounded by a definite sphincter, has a much smaller diameter than the lower extremity of the œsophagus, as great a period being consequently required for the passage of a mouthful of food through the cardia as for its passage down the whole length of the œsophagus.

The stomach can be divided into a larger cardiac part and a smaller pyloric part. The cardiac part consists of the fundus and body, the fundus being the segment of the stomach which lies above a horizontal plane passing through the cardiac orifice. The body is situated entirely to the left of the middle line. In the erect position it is either vertical, or, especially in men, slightly inclined towards the right; in the recumbent position it is always rather more oblique. Its axis is inclined forwards as it passes downwards.

The incisura angularis, a well-marked depression on the lesser curvature, most obvious in the erect position, separates the body from the pyloric part of the stomach, but there is no definite depression on the greater curvature marking the separation. The pyloric part of the stomach consists of the pyloric vestibule and pyloric canal, the termination of which is the pylorus. The pyloric vestibule is directed upwards and slightly backwards as it turns towards the right; it generally reaches just beyond the middle line. The pyloric canal is about 3 cm. in length; it is directed more definitely backwards than the pyloric vestibule, but is inclined slightly upwards and to the right. Its termination projects into the duodenum, producing a striking resemblance to the portio vaginalis of the cervix uteri.

The position of the pylorus is only occasionally marked by a slight constriction on its outer aspect ; it can be more readily recognised by a venous ring, the position of which corresponds closely with it. Both the circular and longitudinal muscular coats are much thicker round the canal than in the rest of the stomach. The circular fibres are disposed in the form of a sphincter, which attains its greatest development at the duodeno-pyloric junction, where it is separated by a connective-tissue septum from the circular coat of the duodenum. Only a few of the longitudinal, more superficial fibres are continuous with those of the duodenum, the majority forming distinct fasciculi, which penetrate the substance of the sphincter, in which some end, whilst others reach the submucous tissue.

FIG. 273.—Diagram from a text-book of anatomy showing position of stomach. (Hertz.)

This shows what was supposed to be the shape and position of the stomach before the radiographic method of investigation was introduced. It is worthy of note, however, that some anatomical writers described a different shape and position. The Edinburgh Stereoscopic Atlas of Anatomy illustrates a stomach which for shape and position might easily be an exact reproduction of the normal stomach as demonstrated by the radiographic method.

The Empty Stomach.—In the empty condition the upper third of the stomach is pear-shaped and contains gas. The rest of the organ passes to the pylorus in the form of a collapsed tube. The pylorus is situated in the transpyloric plane, midway between the upper margin of the manubrium sterni and the upper margin of the symphysis pubis in the middle line, or very slightly to the right. The greater curvature in the erect position reaches the level of the umbilicus or slightly above it. In the horizontal position the stomach lies more obliquely, and the greater curvature scarcely reaches below the pylorus.

The Half-filled Stomach.—When the stomach is partially filled by a standard opaque meal, half a pint in volume, its body is almost uniform in diameter, and its axis corresponds in position with that of the empty organ. As the diameter of the fundus is rather greater than that of the body, a slight constriction marks the separation between the two parts of the stomach. The diameter of the pyloric vestibule becomes slightly smaller as it approaches the pyloric canal. The pyloric canal is always closed, except when chyme is passing through it into the duodenum, although its cavity is generally more or less expanded in post-mortem specimens. Even when the sphincter is relaxed for the passage of food, the canal is so narrow that nothing more than a very fine line can be seen with the X-rays, joining the gastric and duodenal shadows. In the vertical position the greater curvature almost always reaches below the umbilicus, the average distance being $2\frac{1}{2}$ cm. in men and 5 cm. in women. In the horizontal position the greater curvature is on an average 6 cm. higher, its lowest point being consequently above the umbilicus. The junction between the horizontal and descending portions of the duodenum is fixed, but the pylorus is mobile, and in the half-filled stomach it is situated distinctly lower in the erect than in the recumbent

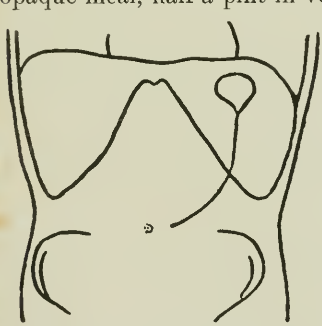


FIG. 274.—The position of the empty stomach. Diagrammatic representation of the screen examination. (Hertz.)

position. The fundus does not drop from the diaphragm when the erect position is assumed, but, as the diaphragm itself falls slightly, the fundus is also a little lower in the vertical than in the horizontal position.

The Full Stomach.—Owing to the greater resistance of the structures in contact with the lesser curvature than those in contact with the greater curvature, when the stomach is filled with a large meal its walls expand more in the direction of the latter than the former, so that its axis comes to lie outside, and below that of the empty and the half-filled stomach. The left dome of the diaphragm is pushed upwards until it reaches as high as, or higher than, the right dome.

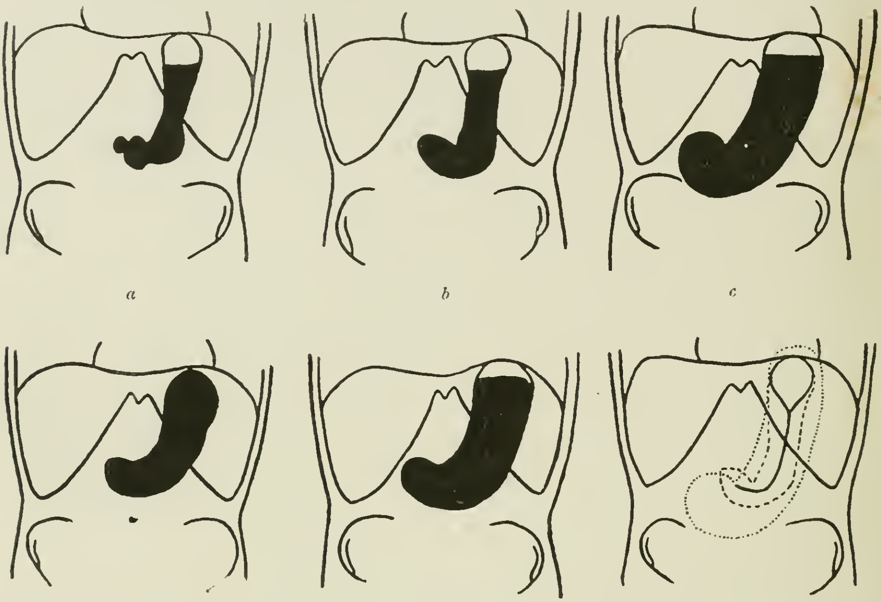


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FIG. 275.—Diagrams showing stages of filling of stomach by opaque meal. (After Hertz.)
(*a*) Stomach as seen after a bismuth meal showing depressions produced by peristaltic waves.
(*b*) Half-filled stomach in vertical position, depressions caused by peristaltic waves not shown.
(*c*) Filled stomach in vertical position.
(*d*) Half-filled stomach in horizontal position.
(*e*) Filled stomach in horizontal position.
(*f*) Superimposed outlines of empty, half-filled, and full stomach as seen with the X-rays in the vertical position.

The diameter of the body of the stomach is so greatly increased that the constriction between it and the fundus disappears. The collection of gas—the "Magenblase" of the German radiographer—is wider and more shallow than that of the half-empty stomach. The diameter of the body is uniform ; that of the pyloric vestibule is almost as great as that of the body, but it diminishes as it approaches the pyloric canal, which invariably remains closed. The pyloric vestibule is so greatly widened that it reaches considerably beyond the middle line, and when viewed from the front completely hides the pyloric canal, which now points either directly backwards, or even slightly towards the left, in spite of the fact that the pylorus itself also moves slightly towards the right.

The Opaque Meal.—The preparation of the patient prior to the ingestion of the meal is a point of considerable importance. Authorities differ as to the exact procedure, and will probably continue to do so, in spite of efforts to establish a standard opaque meal, and a routine method of preparation and examination. While such widely diverse methods as those suggested by Hertz, Morton, and others, and the special technique recommended by Jordan, are used, great discrepancies in results must follow. Given the use of a standard opaque meal, a routine method of preparation, and a definite system of examination, it should be possible for individual observers to establish the appearances of a normal condition of affairs, and from this we should be able to demonstrate marked departures from the normal. In time the results of many observers would harmonise, and definite statements could be made by comparing a large number of such results.

The method of preparation of the opaque meal described by Dr. Morton, in opening a discussion on the standard opaque meal, is that followed by the majority of operators. The average quantity of bismuth oxychloride or carbonate or barium sulphate is about three ounces, the basis of the meal consisting of bread cut into small cubes, the diluting medium being warmed milk sweetened with sugar. The milk is poured over the bread cubes, and the whole is gently mixed, the opaque substance used being gradually added, and the stirring continued until a fairly stiff mixture is obtained. The patient takes the whole of this mixture, and the routine examination is proceeded with.

The following recommendations are the results of the deliberations of a special sub-committee appointed by the Royal Society of Medicine (Electro-therapeutic Section) "to consider and to recommend a Standard Opaque Meal for Radiographic Examination of the Alimentary Canal."

"(1) The standard meal should consist of either bread and milk, or porridge (Note 1).

(2) The total bulk of the meal should be about half a pint.

(3) The meal should be mixed with 2 oz. of barium sulphate or 2 oz. of bismuth oxychloride (Note 2).

(4) The meal should be taken as nearly as possible on an empty stomach.

(5) No aperient or other medicine should be taken within thirty-six hours of the first examination, and if the bowels are not opened naturally, an enema should be given on the morning of the examination.

Note 1.—(*A*) Preparation of bread and milk: 2 oz. of white bread, without crust, cut into small cubes, are placed in the bowl from which the meal is to be taken. Eight ounces of ordinary or malted milk are boiled in a separate vessel with 2 oz. of bismuth oxychloride or 2 oz. of barium sulphate; this mixture is stirred and poured over the bread. Sugar is added to taste.

(*B*) Preparation of porridge: 7 oz. of porridge made from the finest oatmeal are mixed with 2 oz. of bismuth oxychloride or 2 oz. of barium sulphate, and sufficient milk to make the total bulk up to 10 oz. The patient adds as much brown sugar as he likes.

Note 2.—(*A*) Bismuth carbonate neutralises about 22 per cent of the free acids of the stomach, but there is no evolution of gas, as the carbon dioxide is dissolved as rapidly as it is produced (H. Finnemore and A. E. Barclay). The reduction in the acidity of the gastric contents tends to reduce the motor activity of the stomach and to interfere with the normal action of the pylorus.

(*B*) (i) Bismuth oxychloride is slightly more opaque to the X-rays than bismuth carbonate (R. Morton).

(ii) Bismuth oxychloride is about one and a half times as opaque to the X-rays as an equal weight, and twice as opaque as an equal bulk of barium sulphate (R. Morton).

Barium sulphate is preferable, at any rate for hospital use, as it is very much cheaper than bismuth oxychloride and equally good for radiographic examinations."

A preliminary examination should be made of the abdomen before the patient takes the meal, and a plate taken for comparison later on. By this method it is possible to eliminate other conditions than gastric or intestinal lesions. Thus stone in the kidney, pancreas, or gall-bladder may be shown. Dr. Case has obtained a number of excellent plates of gall-stones in the gall-bladder and bile ducts during the examination of a large number of stomach cases.

The stomach should be observed while the opaque meal is passing into it, as valuable data of the normal and abnormal condition of the alimentary tract may thus be obtained.

Franz Groedel used 400 grammes of wheat-meal porridge with 10 per cent of bismuth subnitrate. (This preparation of bismuth, however, is never used now, the carbonate, oxychloride of bismuth, and more recently sulphate of barium being substituted, care being taken that the latter salt is absolutely pure.) He gave the following results :

Stomach emptied in 2 to 4 hours after the meal.
Small intestine emptied in a maximum of 4 to 5 hours after the meal.
Cæcum begins to fill in 2 to 3 hours after the meal.
Cæcum filled in 4 to 6 hours (right flexure).
Transverse colon filled in 4 to 12 hours (left flexure).
Ampulla of rectum reached at latest in 24 hours.

Rieder, using carbonate of bismuth (pure), gives the following results :

Stomach empty in 3 to $3\frac{1}{2}$ hours after the meal.
Small intestine begins to fill in $3\frac{1}{4}$ to 4 hours after the meal.
Small intestine empty in 8 to 9 hours after the meal.

Hertz, using oxychloride of bismuth, gives the following results :

Cæcum visible $4\frac{1}{2}$ hours after the meal.
Left flexure visible $6\frac{1}{2}$ hours after the meal.
Right flexure visible 9 hours after the meal.
Rectum visible 18 hours after the meal.

Groedel, using a meal composed of 250 grammes of barium sulphate, 20 grammes of maize flour, 20 grammes of sugar, 20 grammes of chocolate or cocoa, and 400 c.c. of water, gives quite different results :

Stomach empty in $1\frac{1}{2}$ to 2 hours after the meal.
Cæcum begins to fill in 1 to $1\frac{1}{2}$ hours.

Cæcum filled in 2 to 6 hours (right flexure).
Transverse colon filled in 4½ hours (left flexure).
Rectal ampulla reached 24 hours at latest.

These figures show that with barium sulphate the stomach empties itself just twice as fast as with bismuth subnitrate, and that the carbonate and oxychloride have practically the same action as the subnitrate.

American investigators found the meal based on the original Rieder formula too coarse. It failed to fill out the duodenum sufficiently to allow of accurate diagnosis, and it rarely filled the appendix.

Leonard and George employ buttermilk as the vehicle for the preparation of the opaque meal. This fills out the crevices and folds of the stomach and intestines. As a consequence of this change they claim that the appendix is demonstrated in nearly every case examined.

The formula employed is :

Bismuth subcarbonate . . . 90 grammes.
(Increasing the quantity somewhat when barium is used.)
Buttermilk and water . . . 500 cubic centimetres.

The results obtained when this meal is used cannot be compared with those resulting from the employment of the standard meal, particularly in regard to time of passage through the tract, but as the majority of the American writers base their conclusions on what they describe as the direct method, *i.e.* the demonstration of the actual lesion, it naturally follows that there need be no comparison.

Case advocates, for testing the motility of the stomach, the Rieder meal in preference to the more liquid meals. He also suggests a better method, namely, to add 2 oz. of bismuth to the ordinary breakfast, the bismuth being taken at intervals during the meal. A fluid meal is necessary for the study of the peristaltic waves. and to exclude ulcers, tumours, and indurations of the gastric walls.

Groedel concludes that bismuth somewhat decreases the normal motility of the stomach, and he considers that barium sulphate is the best contrast material for the Röntgen examination of the stomach, and that bismuth leads to false conclusions, since we are dealing only with comparative results.

Corresponding to the increased motility of the stomach we get with barium sulphate an increased flow of well-contrasted chyme in the small intestine, which is markedly more pronounced than after the bismuth meal. This, he holds, is a great advantage for many diagnostic purposes. The duodenum and small intestine are flooded with opaque chyme, and show as ribbon-like shadows, almost as broad as the large intestine. Other advantages of the more rapid emptying of the stomach are that the cæcum is already visible an hour to an hour and a half after the meal, which is much earlier than is the case with ordinary bismuth meal, and that the small intestine is emptied, and the ascending colon filled, much more quickly.

The four opaque substances used have none of them any great influence on the motility of the large intestine, the time of evacuation being approximately the same in all four cases. Hence barium sulphate is the most suitable opaque substance for the Röntgen examination for the following reasons :

(1) It gives sufficient data for the determination of the physiological motility of the alimentary canal.

(2) It is much cheaper.

(3) It stimulates the flooding of the small intestine with a well-contrasting chyme, thus greatly facilitating the Röntgen examination.

(4) The taste of the barium porridge is much pleasanter than that of any other of the opaque meals.

(5) The use of the barium meal is a saving of time, since in consequence of its stimulating action the examination may be made at shorter intervals.

It would appear that none of these four substances necessarily gives the correct time factors on which to base definite conclusions regarding the physiological action of the stomach and intestine, the bismuth salts appearing to delay the motility of the stomach, while the barium sulphate stimulates it. The conclusions we wish to draw, however, are comparative only, therefore it matters little which salt is employed so long as the same one is used in all cases.

A useful routine method for the examination of the intestinal canal, which may be varied to suit the particular case and the convenience of the operator, may be formulated :

(*a*) 9 A.M. Examination of the stomach in the process of filling. Record of the shape and position of the full organ. Screen examination is usually sufficient, but any marked departure from the normal should be radiographed in order that a permanent record may be obtained.

(*b*) 9.15 A.M. Examination of the duodenum, screen and plate if necessary. Serial plates, *i.e.* a number of plates taken in rapid succession, should be exposed at this stage in order to observe the changes at the pylorus and duodenum.

(*c*) 10 A.M. *One hour after the meal.*—Determination of the degree of gastric evacuation. At this stage the small intestine is well seen. In some cases the cæcum may be seen commencing to fill.

(*d*) 11 A.M. *Two hours after the meal.*—The normal stomach is usually nearly empty, the cæcum well filled.

(*e*) 1 P.M. *Four hours after the meal.*—Stomach empty ; small intestine empty ; ascending colon visible.

(*f*) 7 P.M. *Ten hours after the meal.*—The large intestine is visible as far as the splenic flexure.

(*g*) *Twenty-four hours after the meal.*—The large intestine is filled as far as the rectum.

These are roughly the times for a barium meal ; when a bismuth salt is used the time given must be proportionately lengthened.

There are several variations from the routine which may be employed to suit individual cases, *e.g.* the screening may be greatly prolonged when it is desirable to make observations on the motility of the stomach, or in cases of irritable stomach with or without duodenal ulcer. In pyloric ulcer or cancer of the pylorus valuable observations may be made by the screen method.

The radiographic method is of the greatest value when a succession of plates can be obtained, as the stomach may be observed during the process of filling. Small quantities may be watched passing into the organ and taking a definite course along the lesser curvature.

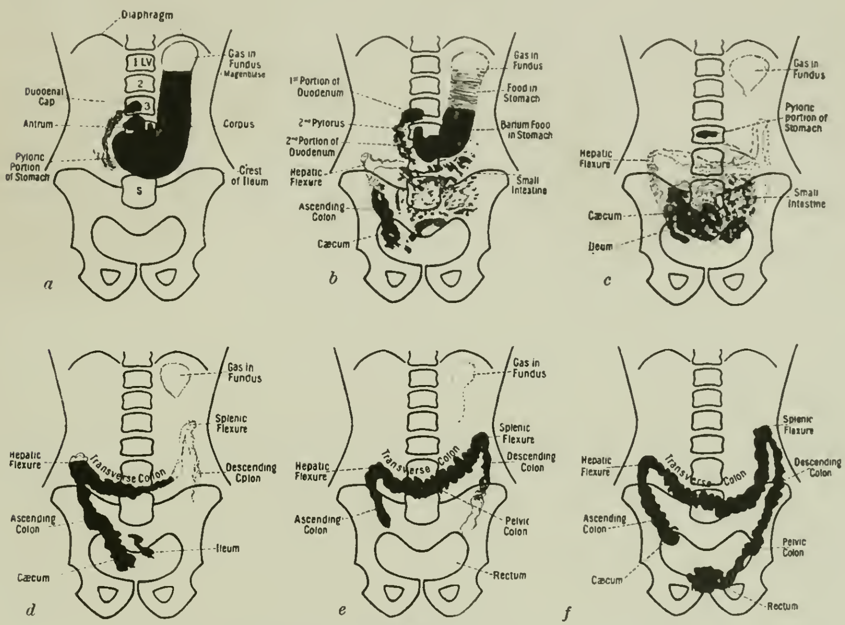


Fig. 276.—Diagrams to illustrate the stages of the bismuth meal.

(*a*) Stomach immediately after ingestion of meal.
(*b*) Two hours after meal taken.
(*c*) Four hours after.
(*d*) Six hours after.
(*e*) Twenty-four hours after.
(*f*) Forty-eight hours after.

According to several American writers there are now two schools: (1) the Continental, basing conclusions on a combination of clinical symptoms and various Röntgenoscopic manifestations of motility; this is defined as the indirect method; and (2) the American, or direct school, basing its conclusions on the exhibition of the lesion itself.

A third school might be referred to, namely, those who for several years have based the diagnosis upon the indirect *and* the direct evidences.

Radiological Divisions of the Stomach.—The normal stomach, as shown by the radiographic method of examination, departs considerably from the appearances shown in text-books on anatomy. The position is somewhat different and the lower limit of the greater curvature is distinctly lower in the abdomen than was formerly believed. Radiography has revolutionised teaching on this point.

The passage of food through the stomach can be watched from its entrance at the cardiac end to its exit at the pylorus. The radiological divisions of the stomach are seen in Fig. 277, and when the screen picture is observed, it is seen that the peristaltic wave passes down from the body of the stomach, commencing at the greater curvature.

The angular notch (incisura angularis) divides the stomach into two

FIG. 277.—Radiological divisions of the stomach. (After Walsham and Overend.)

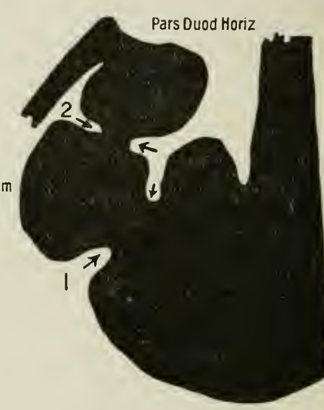


FIG. 278.—The pyloric division of the stomach.
1. Antral constriction.
2. Pyloric constriction.

parts, a vertical and a horizontal. The latter may be seen in various phases of movement to divide into: (*a*) the sinus or vestibule, (*b*) the antrum, (*c*) the pylorus. During the contraction of the antrum the pylorus becomes practically separated by a deep incisure from the sinus. This is termed the antral constriction.

The Normal Stomach as shown by the Radiographic Method.—The appearance of the stomach is shown in Fig. 277. The organ is caught in a phase of the peristaltic contraction wave, and is divided into the following parts:

The fornix or fundus is that portion situated at the cardiac end just beneath the dome of the diaphragm on the left side of the abdomen. It is usually partially distended by gas, and was known also to German workers as the "Magenblase." It is the only part of the stomach seen when the organ is empty. The corpus is the part immediately below the fornix. It is almost vertical in position. The sinus is the lowest part of the organ, and is continuous with the antrum, which is usually distinguished by two well-defined notches. The antrum is that portion situated between the sinus and the horizontal portion of the duodenum. At the junction are two smaller depressions.

The Filling Phenomena of the Stomach.—The significance of the manner in which the food enters the stomach is great, and screen examinations of the organ, while the food is entering, are of great importance. Dr. Jefferson, working in the X-ray department of the Cancer Hospital, London, has paid particular attention to the matter; he

PLATE LXII.—Radiogram of Opaque Meal in Stomach, Duodenum and Small Intestine.

Single flash exposure, with intensifying screen.

From the Radiographic Department of the Cancer Hospital, London, published in the *Journal of the Röntgen Society*.

demonstrates the method of the filling of the normal stomach, and has shown diagrammatically and by radiographs the manner in which the stomach deals with food passing down from the œsophagus.

Jefferson employed a bismuth emulsion and took the pictures after the patient had swallowed four large mouthfuls of the emulsion. He has also constructed models of the normal stomach.

The part of the duodenum which first receives the chyme from the stomach resembles the pyloric part of the stomach. It has been called the cap, or pilleus ventriculi. It represents the proximal part of the first portion of the duodenum. The various stages of the movements can be readily recognised on the screen and shown radiographically on plates. These require to be taken with fairly quick exposure if sharp pictures are to be obtained.

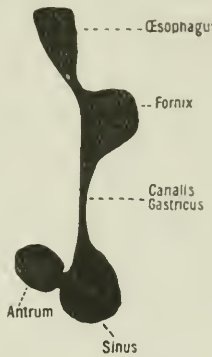


FIG. 279. — Diagram of the typical mode of passage of the opaque food through the human stomach in the upright position. Note the pool of food in the fornix and the descent closely confined to the lesser curvature; a peristaltic wave is indenting the pars pylorica. (After Jefferson.)

Gregory, Cole, and Pirie have shown by serial plates how it is possible to distinguish various conditions due to disease from a study of the changes seen in the "cap."

Attention should also be called to the value of the so-called polygram in gastro-duodenal diagnosis.

Levy Dorn in 1912 introduced a simplification of the methods of Kastle, Rieder, and Rosenthal. It consists of taking two or more exposures on one plate at varying intervals of time. It was allowed to lapse but recently. Gerber has revived its use, and shown, in a paper published in the *American Journal of Röntgenology*, that it possesses some value in diagnosis.

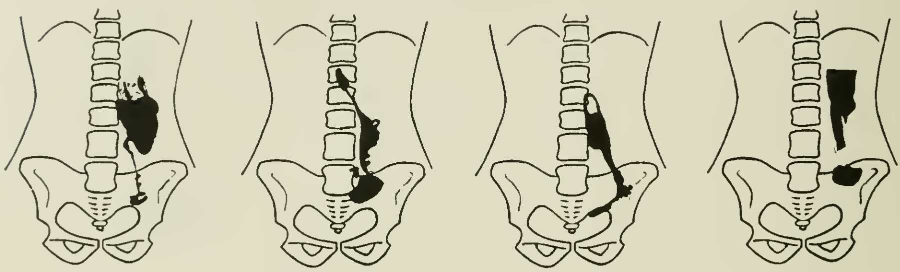
When a small quantity of opaque food in the form of an emulsion is swallowed, it may be seen at the lower end of the œsophagus, where it is momentarily held up. It then flows obliquely towards the left, where it accumulates to form a triangular-shaped shadow, with the apex pointing downwards. This triangular mass continues to increase as the patient swallows more food, the time elapsing before the food passes lower down seeming to depend upon the tonicity of the stomach walls. It also varies according to the type and size of the stomach, as will be seen later on. This phenomenon varies widely in diseased conditions of the organ.

In the next stage a narrow streak of opaque food passes down into the sinus, forming a longitudinal band filling the canalis gastricus, which lies along the lesser curvature.

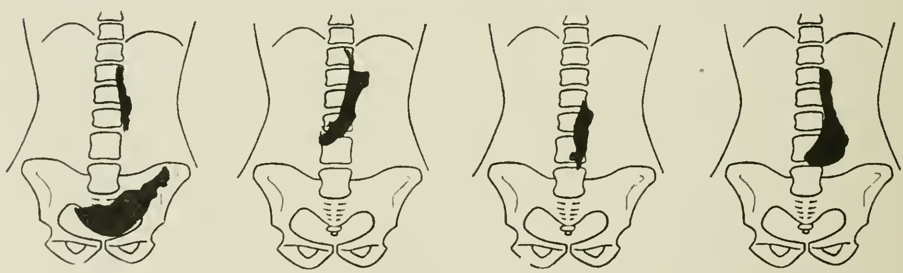
This stage may last only a few seconds, or it may last much longer, according to the tone of the muscular walls. The sinus is gradually distended, widening out from below upwards, until the whole organ is filled, except the air space at the fornix. Variations seen at this stage of the filling phenomena may be indicative of pathological lesions of the organ.

Variations in the Filling Phenomena of the Stomach.—Whenever possible the stomach should be carefully watched while it is gradually filling up with the opaque food. Valuable observations may then be made, and in some instances a diagnosis may be foretold at this early stage of the examination, to be confirmed later when the whole process has been completed.

This method, when employed during the course of a series of bismuth



Hour-glass contraction. | Dilated stomach. Duodenal ulcer. | Dilated stomach. Stomach displaced to left. | Natural stomach. From a case of adhesions of colon. Appendicitis.



Dilated stomach. Pyloric stenosis. Chronic ulcer. | Normal stomach. | Stomach displaced to right by large colon in Hirschsprung's disease. | Stomach slightly dilated. Normal tone in early part of examination.

Fig. 280.—Variations met with in the filling phenomena.

These are very instructive, since it is often possible to foretell the type of stomach under examination by an observation made in the first few minutes.

meal examinations, gives fairly accurate indications of the type of stomach under examination. In all the cases shown in Fig. 280, the radiographs were taken after the patient had swallowed six spoonfuls of the barium meal in the upright position.

The actual time at which the picture was obtained after the commencement of the meal varied with the rate at which the patient could take the food, but in no case did the time exceed five minutes from the commencement.

Very valuable information is obtained by this method, and when a large number of cases have been recorded, an examination of the results shows that the stomachs met with vary from a perfectly normal condition to the most marked departures from the normal. The various types of stomach may then be sorted out and a complete record kept of the filling phenomena and the movement of the normal stomach.

Hertz has demonstrated the various types of stomach, making most of his observations on the screen.

Examination of the Stomach after Completion of the Meal.—Having made these preliminary observations, a plate is taken on the completion of the meal. A record of the full stomach is then obtained, and comparisons may be made in the same way, noting the various departures from the normal. The size is noted, then the shape and position of the organ in the abdominal cavity.

A comparison of a large number of fully distended stomachs enables us to arrive at an approximate idea of the normal type and all departures from this type.

Variations again divide into (*a*) the slight departure which may be regarded as normal, and (*b*) the gross departure met with in various forms of disease. It is possible in some cases to diagnose the presence of an ulcer or growth by carefully scrutinising the outline of the bismuth-filled stomach. Variations in the peristaltic wave also serve to indicate departures from the normal. The presence of a particular departure from the normal in a case extending over a length of time and screened at repeated examinations, will indicate the presence of an ulcer or new growth, and these two require to be differentiated the one from the other.

Modifications of the Opaque Meal for Special Investigations.—The bismuth or barium sulphate may be made very thin and a small quantity given when we wish to test the motility of the stomach carefully. There are other modifications of the opaque meal which are useful. Haenisch recommends the following method for the investigation of the large intestine :

Thoroughly mix 500 grammes of warm water with 300 grammes of kaolin and 150 grammes of barium sulphate ; then add 500 grammes more of warm water, and finally 150 grammes of barium. To inject, introduce a soft rectal rubber tube a few inches into the rectum. To the outside end of this attach a few inches of glass tubing (thus enabling the injection to be seen), from which india-rubber tubing is led to a douche can. Place the barium solution in the can, and raise it to allow the injection to flow. The patient is lying on a couch with the X-ray tube below, and the injection is watched upon the fluorescent screen ; then by lowering the can the injection will flow from the bowel, and thus any abnormal condition can be studied with the solution flowing in either direction.

Amongst other modifications reference must be made to that of Jordan, described in the section on the duodenum.

Haudek's Double-meal Method.—A bismuth meal is given at a particular hour, and the stomach is examined six hours later for residue or otherwise and the bowel for the position of the meal. A watery infusion of bismuth is then given, to determine the size, shape, and motility of the stomach itself. This method allows of the whole examination being made at one sitting, and certainly shortens the time during which the patient is under observation. On the other hand, it is not reliable, and in some cases many observations require to be made. This method is capable of further modification. Instead of the watery infusion a complete barium meal may be given. The whole of the intestinal tract may then be shown. In patients suffering from intestinal stasis, this method of examination is not very satisfactory. The second meal quickly overtakes and becomes mixed with the first, and some confusion arises in the conclusions drawn from the first stages of the examination in these cases.

Precautions to be observed in the Conduct of the Examination.— With the screening-stands and tables now in use, the distance is sufficiently great to prevent any serious damage to the patient with prolonged screening ; but where, as often happens, the operator is not fully equipped for this class of work, and where his apparatus is not sufficiently powerful to ensure satisfactory results, he is tempted to approximate the tube and patient as closely as possible, and, if great care is not exercised, the skin in sensitive patients may be severely damaged. Under such conditions prolonged screening should be avoided. When it is necessary to screen thoroughly the patient should be at least two feet from the anti-cathode of the tube, and even then the interposition of a thin aluminium filter will be a safeguard. In cases of doubt it is better to test by placing a Sabouraud pastille or Kienböck paper in the position occupied by the patient, and allowing the tube to run for the length of time which would correspond to the full examination contemplated. A comparison of the pastille or paper with the usual standards will show approximately the dose which would be administered to the skin surface during the examination. In this way it is possible to prevent damage to the patient and anxiety to the operator.

The value of an X-ray examination of the stomach is great, but reliance should not be placed on it alone. Repeated examination should be made and chemical examinations carried out simultaneously, and, lastly, full consideration should be given to the history of the case and the palpation of the stomach at the time of the examination.

The After Technique of the Opaque Meal

This is an attempt to systematise briefly the ordinary technique of the opaque meal in order that the advantages to be derived from it may be summarised, the records be readily referred to, and the physician or surgeon may have at hand a complete record of the examination.

The following procedure is an elaboration of what might be referred to as the after technique of the barium meal examination, in so far as it supplies a practical method which as far as possible reduces everything to a standard.

The method consists in taking tracings from the plates which have been exposed and developed, or reduced outline drawings from the tracings already obtained ; when the plates are dry the record may be prepared.

A pantograph is employed to reduce the tracings to a convenient size; the working of this instrument is extremely simple and accurate. An outline drawing is provided on sheets of paper; this has been prepared from a study of a number of radiographs, and may be regarded as the standard chart (Fig. 281).

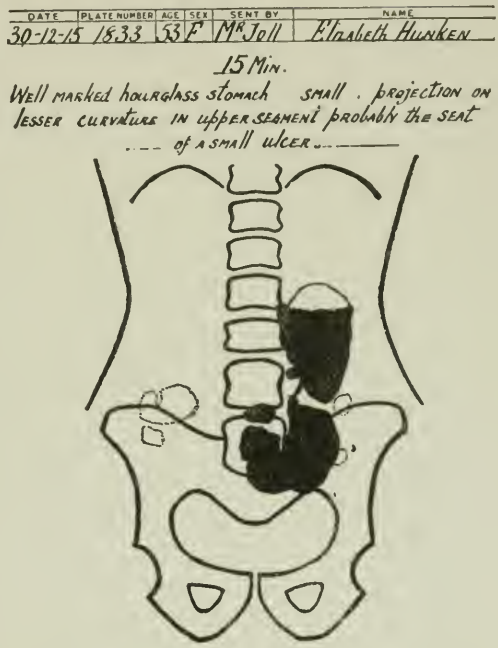


FIG. 281.—Showing diagram drawn in by means of the pantograph, particulars of case, and description of the conditions found.

The number of tracings will vary in individual cases, but as a rule six form a convenient number for most purposes. These are photographed together on one whole plate.

A special table has been designed to facilitate the tracings of the negatives. Figs. 282, 283, and 284 illustrate the general plan of the table; the table top is drawn to scale, as is also the elevation plan, and all the necessary dimensions are figured, so that any one can construct it from the plan. On the right-hand side of the table top a large hole is cut; into this a piece of thin plate glass is accurately fitted, its surface being flush with the table top. The negative to be traced is placed film down upon the plate glass, so that the spine corresponds with the vertical thread V, which is stretched below the glass. Beneath the table is a board R, covered with white paper. The reflected light is obtained from a lamp L, controlled by the switch S. The reflector is hinged to

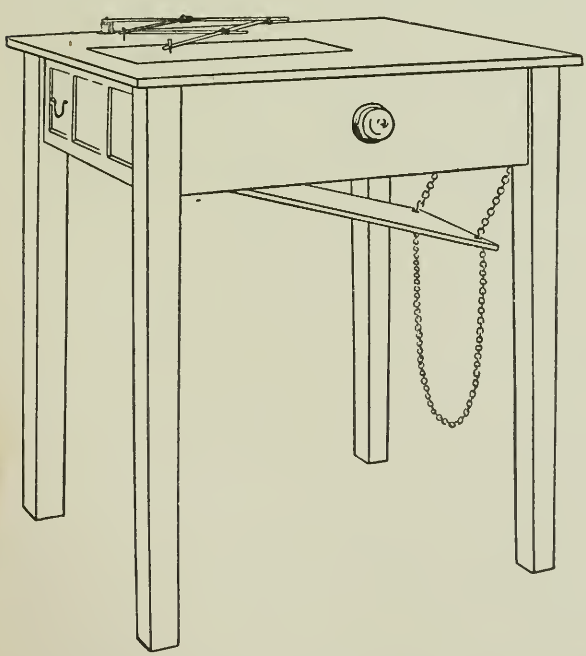


FIG. 282.—Showing general construction of table.

the table rail, and the angle adjusted by a string or fine metal chain. A card, similar to Fig. 281, on which the tracing is made, is slipped under the heads of drawing pins at the corners. Once the relative position of negative and card have been found the drawing pins need not be removed, they form fixed points for controlling the position of all the cards used. A pantograph works from the fixed point P. This consists of a brass pin let into a brass plate, and forms a convenient point from which the pantograph may be worked. The plate is "flush" with the table top. The pin can therefore be withdrawn at any time, leaving the table top clear for other work.

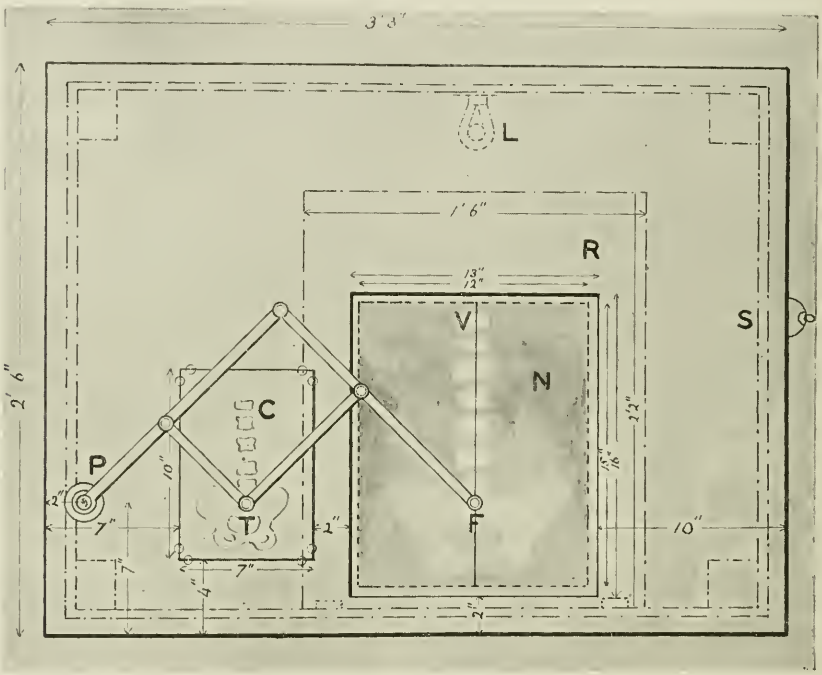


FIG. 283.—Plan of table-top.
Showing pantograph in position, negative in illuminated window, and diagram in position for tracing.

The outline of the opaque food in the stomach and intestines seen on the negative is carefully followed with the tracer F, the reduced copy is traced on the card by the pencil T. The degree of reduction may vary, but a convenient size is about $2\frac{1}{2}$ to 1. The card used is 10 inches by 7 inches in size. and has a space at the top for details of the examination, hospital records, and any other particulars required.

Each negative is traced in the same way.

When all the tracings are completed, the outlined parts are filled in with drawing ink. Variations in density may be shown by varying the depth of the colour. A complete set of drawings has now been prepared and all data of exposure times, positions of food, etc., may be printed on the cards with the particulars relating to the patient. Much time and labour can be saved by having a set of rubber stamps prepared with the names of parts (see Fig. 285). Each diagram can then be quickly lettered as indicated.

The complete set is now fixed upon a convenient white board, fitted with slots for the accommodation of the drawings, and the set is then photographed upon a whole plate and developed. The plate when dried is ready for printing (see Fig. 287).

The finished print furnishes, on a convenient size of paper, a complete record of the examination, which may be sent to the wards or to the physician or surgeon, and this furnishes him with a convenient reference which may be incorporated in the notes of the case.

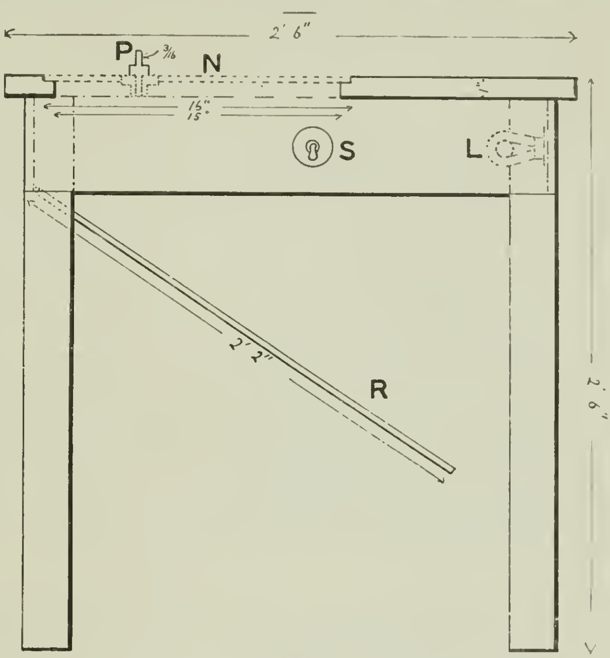


Fig. 284.—Elevation of table-end.

The method described is subject to considerable modification. When it is necessary to save time the tracings may be drawn upon reduced charts on a case sheet and the photographic process omitted. The drawings may be reduced to a convenient size by the pantograph, and the complete set is ready for the consideration of the surgeon. This could quite readily become a routine method and would be found useful in general hospital or military work.

In the photographic method of reduction the intermediate stage of making a negative may be left out and the reductions can be made upon a bromide paper. This saves a considerable amount of time. The whole process need not take more than an hour or two if the paper is quickly fixed, washed, and dried.

It may happen that the radiographer may wish to send out prints from the plates—these, when of full size, are too bulky for convenient use; in order to reduce the inconvenience to a minimum I have had prepared for me a large viewing box which will accommodate six plates, 15 by 12 in. size. Convenient blinds are provided for screening purposes; the six plates can be reduced at one exposure to a whole or a half-plate size. When a print is made from this plate the complete record is now ready for the surgeon, and may take the place of the tracings described above or may accompany them when both are required. The surgeon is now completely independent of the original plates—these are, therefore, stored away and may not be required again, except when questions of detail arise. The set of tracings, negative and print, are also stored in an envelope, indexed, and placed in the filing cabinet.

The chief object of this technique is to provide a convenient record of radiographic work for the use of the physician or surgeon, but there are other conveniences, chief of which may be that of the radiologist, for when he comes to compare a large number of cases the prints obtained of the complete examination are most convenient ; he can carry a hundred or two of these records, and when comparing the sets they are much more conveniently handled than the original plates.

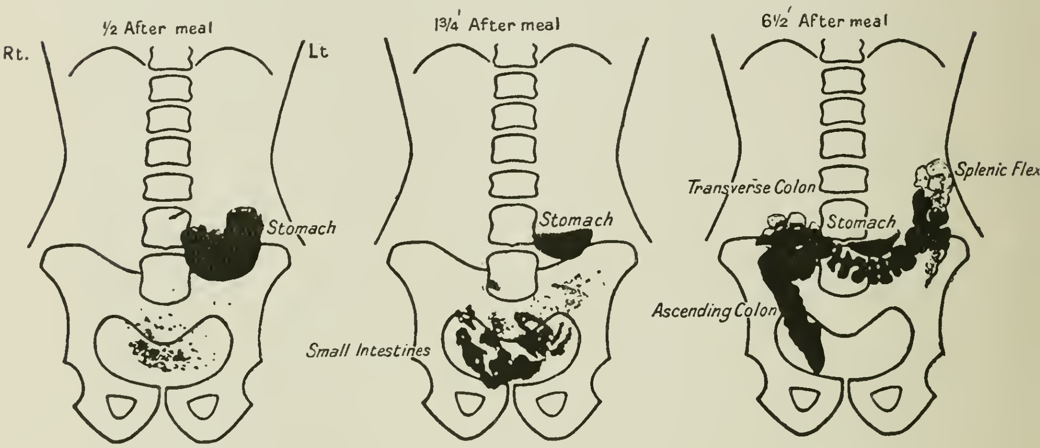
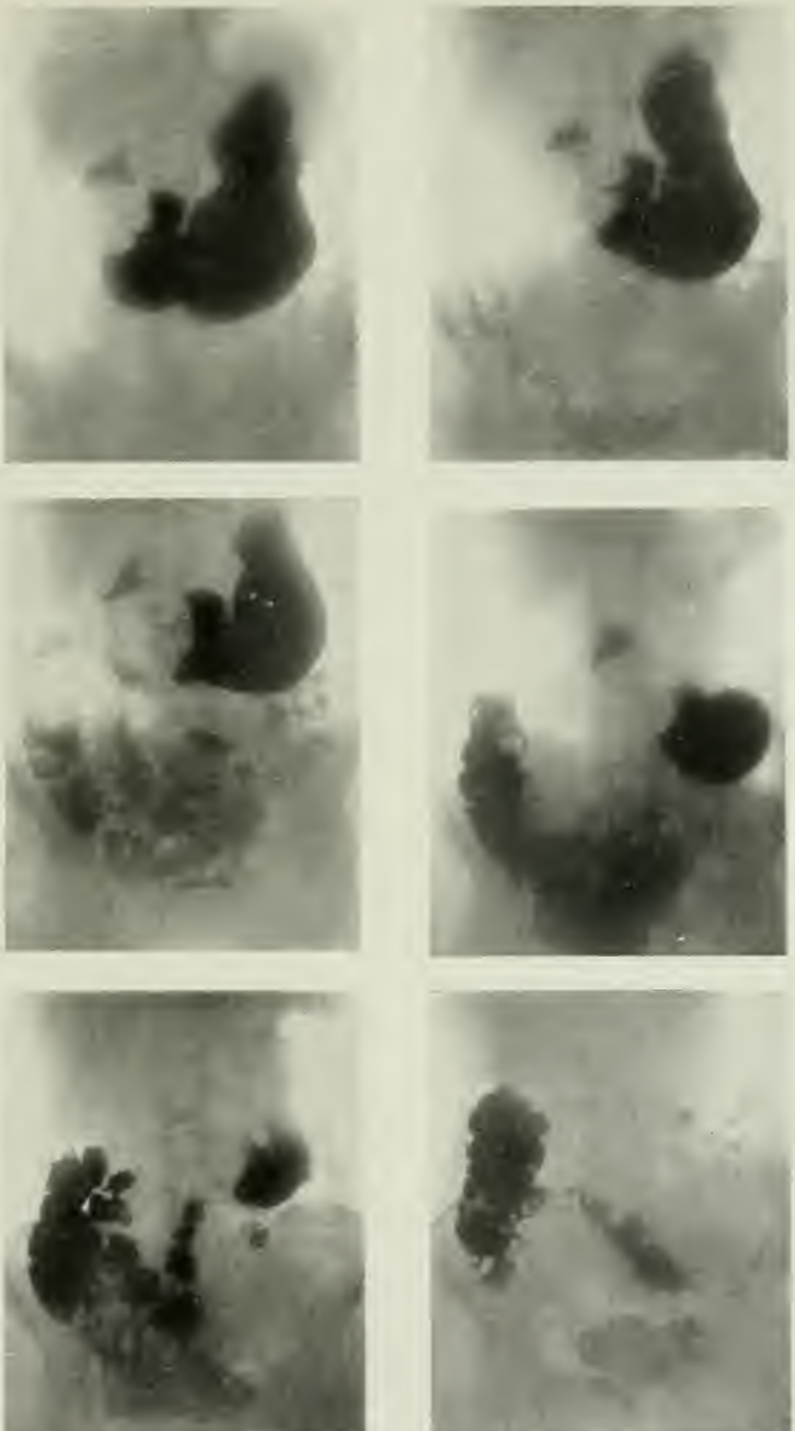


Fig. 285.—To show the marking of the parts ; this is arranged for by having a complete set of rubber stamps prepared.

A further advantage will be found when it is desired to prepare cases for publication.

In order to illustrate further the advantages of a technique of this kind, a number of reductions from 15 by 12 plates are shown (see Plates LXIII. and LXIV.). The reduced prints are undoubtedly the more complete so far as the record is concerned, but it is not always possible to get a uniform set of negatives from which to obtain the reduction, a negative which will give a very poor reduced print may be quite good enough to give a good tracing, so in some cases it may be well to use both methods. A number of tracings of the screen examination may be available when no negative has been taken ; these tracings may be placed upon the table and reduced by using the pantograph. By using the combined method the record of the case may be rendered more instructive and complete than when either is used alone. The table may be used for other purposes than that of the opaque meal. Negatives of other subjects may be readily reduced.

I have been greatly helped in the development of the technique described by Mr. St. George Caulfeild, who is responsible for the production of the table



¼ hour — 1 hour

3 hours — 5 hours

7 hours — 24 hours

PLATE LXIII.—Carcinoma of the Stomach indicated by Marked Deformity at Pyloric End of the Organ.

Plates taken ¼, 1, 3, 5, 7, 24 hours after ingestion of meal.

From "After Technique of the Opaque Meal," published in the *Archives of Radiology and Electrotherapy*, 1917.

¼ hour

1 hour

2 hours

4 hours

7 hours

24 hours

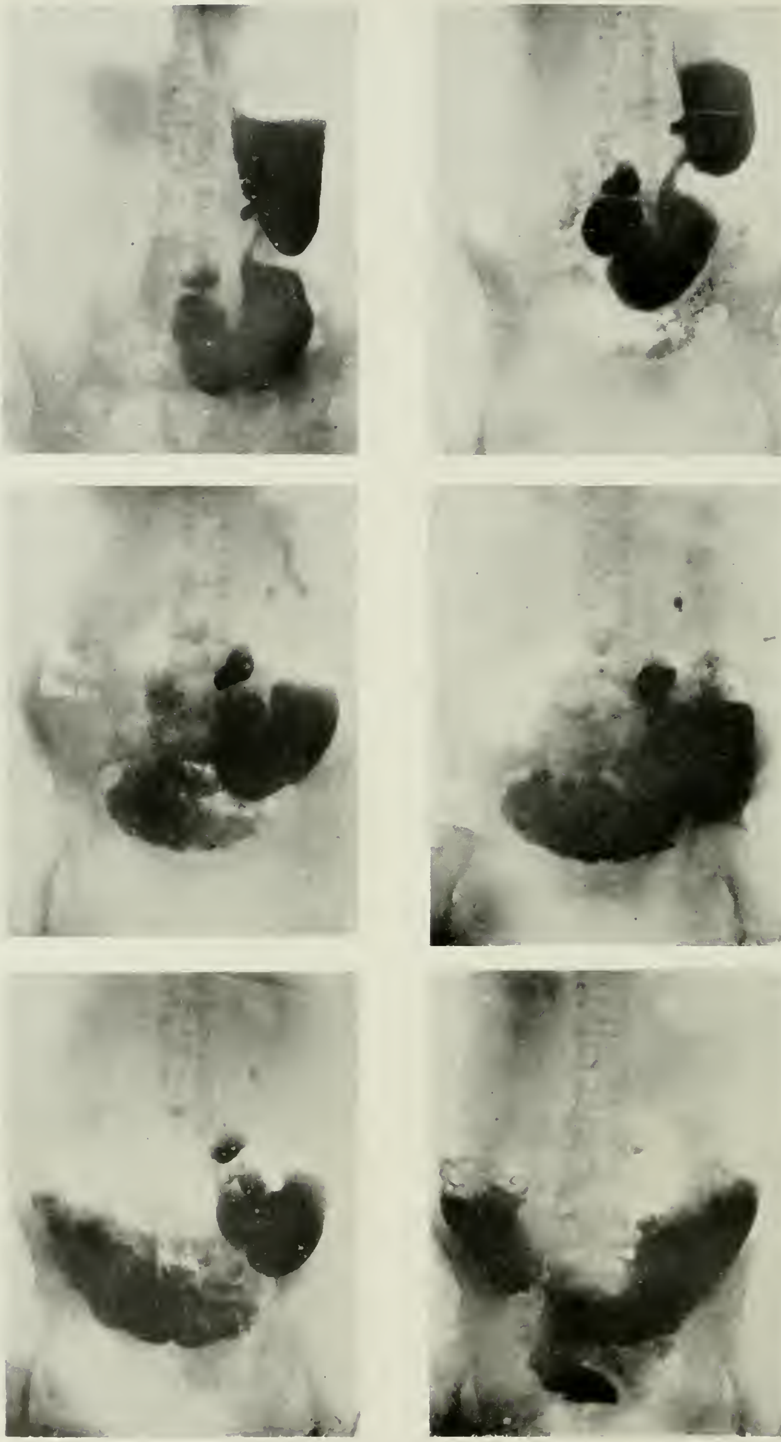


PLATE LXIV.—Hour-glass Contraction of the Stomach.

A small penetrating ulcer is seen on the lesser curvature.
Plates taken ¼, 1, 2, 4, 7, 24 hours after the meal.

From "After Technique of the Opaque Meal," published in the *Archives of Radiology and Electrotherapy*, 1917.

and the excellent scale drawing which illustrates it, and to Mr. Holland for designing the large viewing box used for the photographing of the large plates, and also for perfecting the photographic technique of the method.

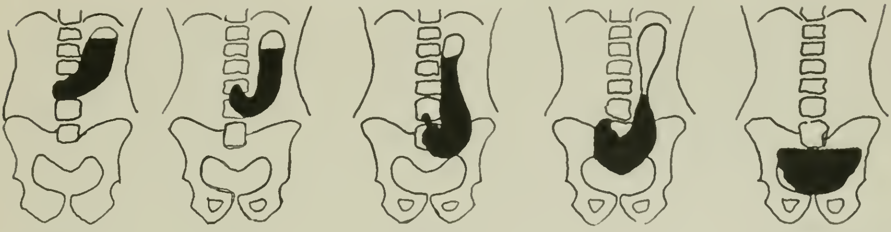


FIG. 286.—Diagrams illustrating variations in the shape of the stomach.

The first four figures are recognised as types of stomach which, while varying considerably, yet show no marked evidence of gross disease distinguishing them from the forms where disease is present; each has a definite significance in the interpretation of the results obtained, and may be associated with a definite train of signs and symptoms in relation to the various diseases met with in other portions of the alimentary tract.

Variations in the Position and Size of the Stomach.—The normal stomach is variable in form and position. There are certain types which must be considered normal since each is capable of performing its normal

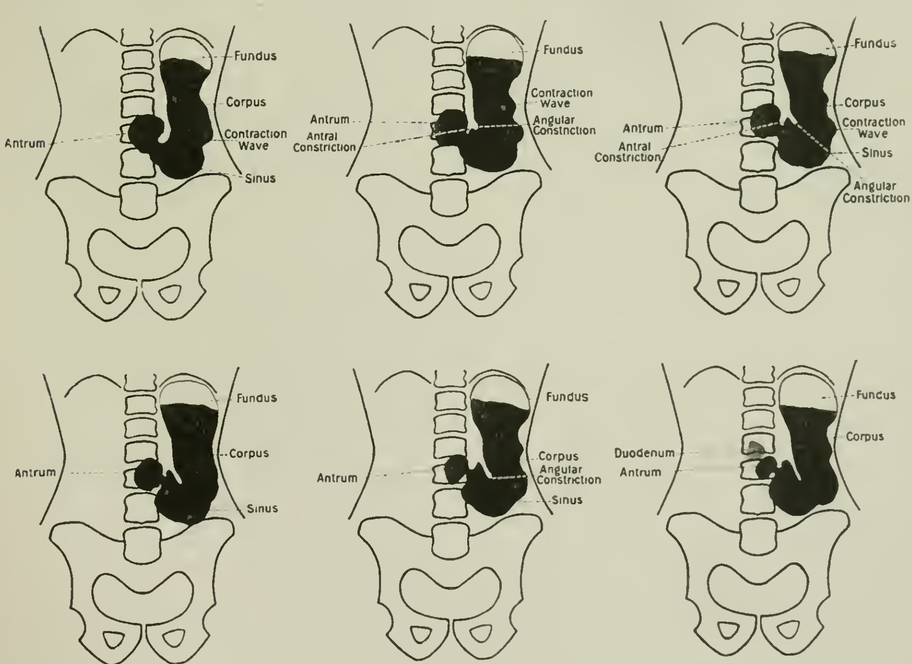


FIG. 287.—Stomach showing successive contraction waves.

function. Later anatomical studies undoubtedly prove that the living stomach is correctly shown by the Röntgen picture. Variations in the shape and size of the normal stomach have been described; but radiographic interpretation would be facilitated if the division into groups according to muscular tone were adhered to in the future, these groups being of the hypertonic, orthotonic, hypotonic, and atonic forms. These are illustrated diagrammatically in Fig. 286.

The emptying time, or normal period taken to empty these different types of stomach of the opaque meal, is an additional aid in differentiating each type. When bismuth salts are employed the hypertonic requires from two to three hours to empty itself, the orthotonic three to five hours, the hypotonic four to six hours, and the atonic six to eight hours.

The form of the normal stomach and its position depend largely upon the shape of the upper abdomen and the general anatomical characteristics of the individual. When the intercostal angle is wide and the upper abdomen is broad, the stomach assumes an oblique position. With a narrow upper

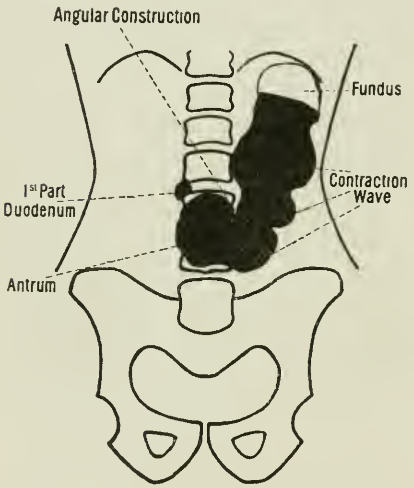


Fig. 288.—Stomach showing irregular contractions.

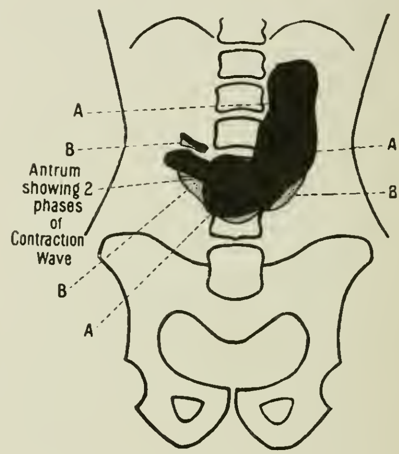


Fig. 289.—Stomach showing active contractions. Two exposures on one plate.

abdomen and a more acute intercostal angle, the stomach is perpendicular. Thus, in some individuals an atonic type of stomach is normal, *i.e.* if its function is not delayed, while the same type in an individual of a different build, but incapable of emptying itself, is the result of a ptosis. Again a hypertonic form of stomach may be found where the abdomen is broad and the intercostal angle wide, and yet it will be found to simulate an orthotonic or even hypotonic stomach.

The Movements of the Normal Stomach.—The movements of the stomach can best be studied by observing: (*a*) Changes taking place during a screen examination. These observations may, however, be recorded on the photographic plate, and by comparing a large number of plates taken during the examination the peristaltic wave may be reconstructed and illustrated diagrammatically.

The contraction wave commences on the greater curvature of the corpus, and is propagated as a slowly recurring series of annular contractions, which become deeper as they approach the pylorus. A complete peristaltic wave occupies with the shorter diastole about twenty seconds in all.

(*b*) By means of a number of plates taken in rapid succession, it is possible to demonstrate the peristaltic wave by a method of pseudo-cinematography. This has been done by Rieder and Rosenthal and other investigators, notably Cole and Pirie. Walsham and Overend have added further to our knowledge of the movements of the normal stomach, as also has Barclay, who has called attention to the many variations from the normal and their significance in diagnosis, based chiefly on the radioscopic method.

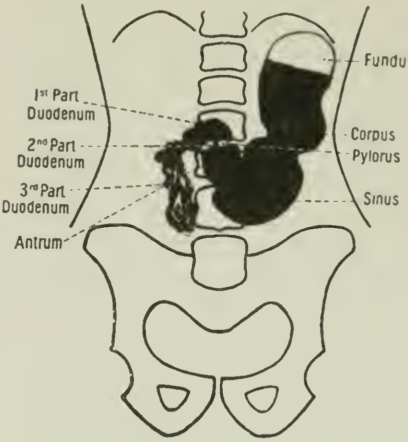


Fig. 290.—Stomach showing irregular contractions and food passing through the duodenum.

Radiographic Appearances.—Holzknecht, in an exhaustive paper on the bismuth examination of the stomach, groups radiographical and clinical signs under one "symptom complex," so as to show their true diagnostic value.

This is a most important step in technique. Clinical signs and symptoms should always be considered together with the radiographical findings, if we wish to get the best value from the examination. A consideration of the clinical signs will often determine the exact method of investigation we should employ, and will save time.

He describes a number of groups; two examples will illustrate the method:

Symptom Complex A.—(1) Bismuth residue six hours after meal; (2) normal shadow of stomach seen on the screen; (3) achylia.

Diagnosis: a small carcinoma of the pylorus.

Symptom Complex B.—(1) Small bismuth residue after six hours; (2) sensitive pressure point and resistance in the pars media; (3) transverse contraction of the pars media; (4) diverticulum, without an air bubble in the small curvature; immovable.

Diagnosis: a callous ulcer of the small curvature of the pars media.

He lays great stress upon the importance of hyperacidity or otherwise, and many of the X-ray diagnoses are based upon the X-ray findings, plus or minus the acidity. Thus in Symptom Complex A the diagnosis is made on the following points: (1) As long as the pylorus is free, achylia is always associated with hypermotility in an empty stomach in from two to three hours; (2) a residue after six hours must mean organic obstruction; (3) spasm of the pylorus is never associated with achylia but with hyperacidity.

The X-ray findings may be diagnostic of a lesion at the pyloric end of the stomach, *i.e.* simple ulcer or malignant disease. In the former the ulcer may be overlooked by the radiographic method unless many serial plates are taken ; but if the case is observed on the screen the presence of the ulcer may be suspected from the absence of shadows indicating the passage of food through the pylorus. In malignant disease involving the lesser curvature and spreading round the pylorus, the latter point is more or less fixed, and held higher up than usual; and food may be seen passing through the stricture ; a sharp and persistent angle or irregularity in the pyloric region is generally indicative of malignant stricture; finally, a shadow of the growth may at times be seen on the radiographs.

Rieder and Rosenthal have demonstrated the normal and abnormal contractions of the stomach wall by a method of cinematography. They take 8 or 9 pictures in rapid succession. An outline sketch is taken of each on transparent paper, the whole are superimposed, and a picture obtained of a peristaltic wave passing along the whole organ. Definite departures from the normal are indicated by an arrest of the contraction wave at one particular spot, showing the presence of an ulcer, which may be simple or malignant.

Functional Disturbances of the Stomach.—*Tonicity of the Stomach.*—The phenomena observed while the opaque meal is passing into the stomach. The manner in which the opaque meal enters the stomach is an indication of its muscular tone. The empty normal stomach lies in the form of a collapsed tube, with its walls in contact, except in the fundus, which contains the so-called magenblase. (See Fig. 274.) A portion of the opaque meal is first seen in the upper part as a funnel-shaped shadow, which is quickly forced downwards, separating the walls, and finally reaching the sinus, and filling the pyloric canal. The length of the stomach remains fixed, while the corpus, sinus, and pyloric canal increase in girth, and accommodate themselves to the amount of the meal ingested. This type of filling phenomena is characteristic of the orthotonic stomach. In contrast to this, the opaque meal in entering an atonic stomach seems to fall through the corpus directly into the sinus. The direction of the passage of the meal is outwards and downwards to the left.

In a markedly atonic stomach the distension commences in the sinus, the opaque meal collecting there in a half-moon form, while the walls of the body remain in contact, and the fornix filled with gas preserves a more or less oval form. Gross changes in the contour of the stomach can be observed during the ingestion of the opaque meal. The benign and the malignant hour-glass stomach differ entirely in filling phenomena from the normal stomach.

The Motility of the Stomach.—Definite conclusion as to the motility of the stomach can be arrived at from the study of the swaying intensity and form of the peristaltic waves, and the time required for the opaque meal to pass, when combined with the information given by the shape, position, and form of the residue remaining in the stomach. These peristaltic waves can be shown on the fluorescent screen. The late Dr. Leonard showed that there is a constant change in the length and breadth of the stomach during every

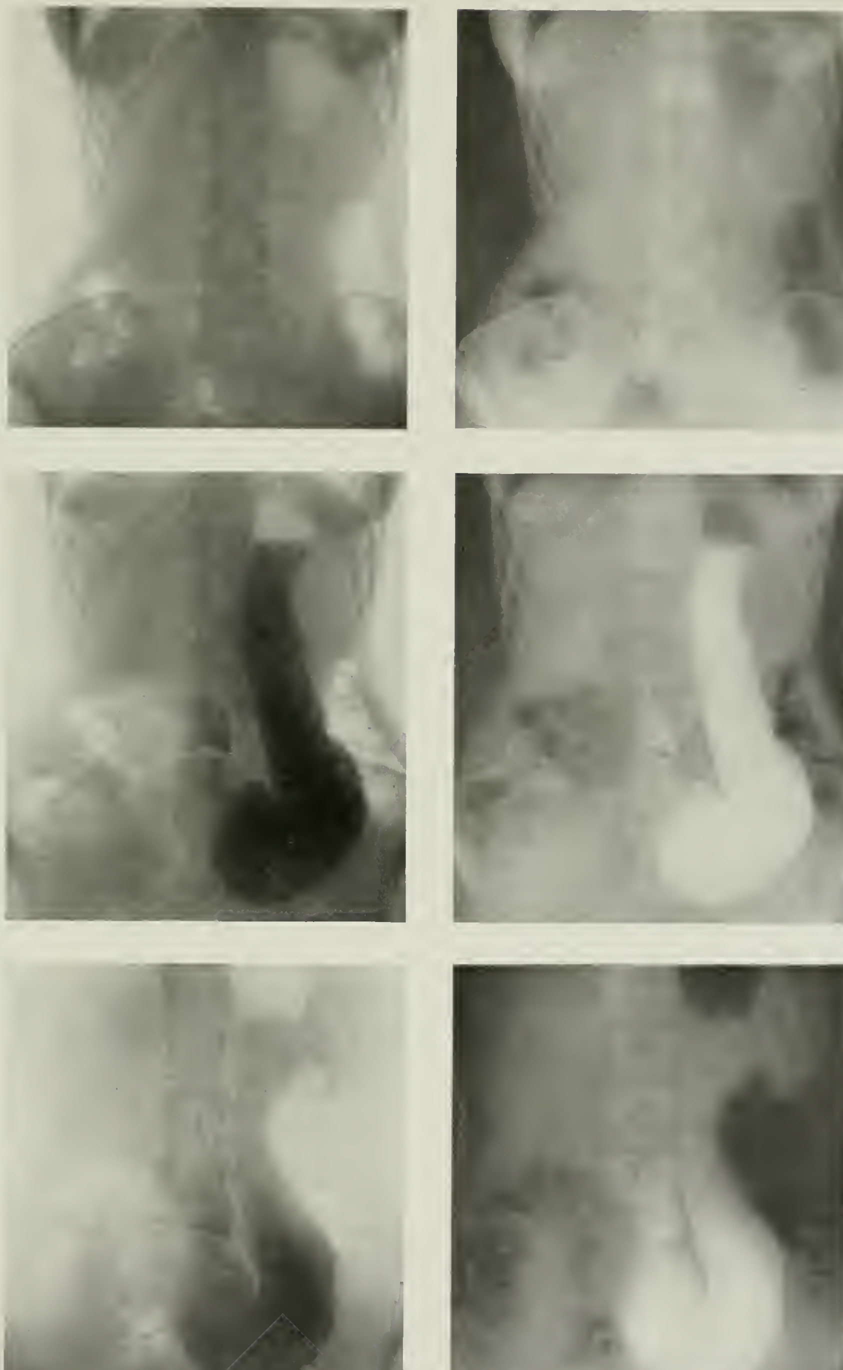


PLATE LXV.—STOMACH AND COLON SHOWING VISCEROPTOSIS.

a, Abdomen before the meal ; this shows the shadows caused by gas in the stomach and large intestine.

b, Stomach well filled, situated low down in the pelvis, elongated.

c, Stomach emptying slowly about 2 hours later.

a

b

c

PLATE LXVI.—STOMACH AND COLON SHOWING VISCEROPTOSIS.

Same Case as in Plate LXV.

a, Six hours after ingestion of food, stomach still containing considerable quantity of food.
b, Two hours later, eight hours after ingestion, stomach contracting vigorously on the bismuth residue.
c, Twenty-four hours after meal: food in colon.

cycle of respiration. It has been noted by surgeons, during operations under anæsthetics, that while peristalsis is absent and the sphincters are relaxed, the contents of the stomach are ejected into the duodenum in jets synchronous with the respiratory movements.

The form and depth of the peristaltic wave differ in the varying types of stomach, and in the same stomach with the patient in different positions. It also varies with the character of the ingesta.

The Time taken by the Stomach to Empty.—The relation of the emptying time of a stomach to that of the normal type is the most accurate way of determining its motor efficiency. Thus, as already stated, it has been determined that the emptying time of the four types of stomach is as follows:

A standard Rieder meal of 350 grammes of food and 50 grammes of bismuth should pass through the hypertonic stomach in two or three hours, the orthotonic in three to five, the hypotonic in four to six, and the atonic in six to eight hours; the presence of a residue of bismuth in a stomach of any one of these types, after the normal time for that type, shows that there is deficient motility. Differences will be found to occur according to (*a*) modifications of the quantity of food and bismuth, (*b*) the substance used to render the meal opaque, and (*c*) the placing of the patient in different positions. As far as possible the examinations should be made in the upright position, the recumbent position being used in most cases as a check observation. No other food should be taken by the patient until the stomach has emptied itself, or until the observer has determined that no further observation on the emptying time of the stomach is necessary.

The time taken by the stomach to empty itself is of the greatest importance. The normal stomach should be empty in about three hours, though the actual normal time is difficult to ascertain. Important as this may be, it is of still greater moment to observe the nature of the passage of the food through the pylorus. A screen examination is very valuable at this stage, for often it is possible to detect a narrowing of the pyloric canal by ulcer or growth, and often a diagnosis may be made.

Variations in the Emptying Time of the Stomach and their Diagnostic Significance.—Rapid emptying of the stomach is found in a number of conditions.

(1) *Catarrh of the Stomach.*—Due to many causes, chronic alcoholism, septic gastritis.

(2) *Duodenal irritation*, from any cause such as ulcer. A small irritable ulcer may lead to the rapid evacuation of the meal.

(3) *Malignant disease* of the stomach may involve a large portion of the organ, and give rise to the "water-bottle stomach," which may rapidly pass the food through into the duodenum.

(4) Patients who have had a *gastro-enterostomy* performed at an earlier date rapidly empty the stomach. The food should be seen passing through the new opening.

(5) *Multiple small ulcers*, which lead to an irritable condition of the stomach, may in some cases lead to a rapid emptying of the organ.

Delay in emptying may result from a number of causes :

(1) Atony of the stomach walls, met with in (*a*) simple atony ; (*b*) gastroptosis, associated with general visceroptosis ; (*c*) chronic ulcer of the pylorus, leading to stenosis, and in time to very marked dilatation of the stomach ; (*d*) malignant disease of the pylorus.

(2) Lesions of the large intestine, ileal stasis, adhesions of the colon to other parts or to parts of itself, frequently associated with the presence of appendicitis (chronic).

Observations on the Emptying Time of the Stomach in Chronic Inflammatory Conditions of the Tract, etc.—(1) The practical outcome of observations made on a large number of cases where at operation adhesions or inflammatory changes have been found in the region of the gall-bladder and vermiform appendix is as follows :

In the latter region marked changes in the appendix with adhesions to surrounding parts have frequently been found ; in other cases the formation of a well-marked Jackson's membrane has led to changes in the time factor.

It would appear that in some instances these various changes lead to alterations in the time factor of the passage of food through the stomach and intestine. In a number of cases the time factor is accelerated. In a larger percentage of cases it is greatly lengthened.

It is probable that these factors, *i.e.* morbid conditions, account for both the lengthening and shortening of the time.

Adhesions following upon Abdominal Operations.—(2) Some types of duodenal ulcer may lead to delay in emptying, though the small irritable ulcer of the duodenum is generally associated with rapid emptying of the stomach.

(3) Several cases have been met with where disease of the gall-bladder appeared to be the only explanation of delay in emptying—one a case of inflammatory change, and another where malignant disease, involving the gall-bladder, caused considerable delay in emptying the stomach.

In the case of the gall-bladder conditions, it is not at all unlikely that in the earlier stages a degree of irritation exists which, acting irregularly on the duodenum, causes a rapid emptying of the stomach, but later, when the duodenum becomes more tolerant in its reflex action, the emptying time becomes delayed. The same reasoning applies to those cases where the irritating lesion is much lower in the canal, *i.e.* at the cæcum or its neighbourhood. In the earlier conditions of disease involving the duodenum, before marked adhesions lead to organic difficulties, the reflex irritability of the duodenum is stimulated and the stomach empties rapidly. A continuation of this irritable condition will lead to a degree of hypertrophy of the stomach wall which may lead to still more rapid emptying of the contents.

At a later stage, when chronic adhesions have given rise to mechanical difficulties, the stomach contents are delayed in transit, the stomach after a time becomes atonic, dilatation follows, and the emptying time is still further delayed.

It would appear, therefore, that there are two stages in the conditions following upon inflammatory and like changes in the alimentary tract: (1) An irritative stage, where all the functions are accelerated, and (2) a stage of mechanical obstruction, leading to a degree of hypertrophy of the stomach and compensatory changes, with (*a*) direct mechanical difficulty, and later (*b*) atony and dilatation of the stomach, when failure of compensation sets in.

The condition of the stomach actually found at operation will depend therefore on the stage of the process at which the operation is performed. In the early stages a normal or slightly hypertrophied stomach is found, and in the latter ones an atonic dilated stomach with marked delay in emptying of the organ.

Pathological Conditions of the Stomach.—The excellent summary of these conditions by the late Dr. Lester Leonard, in his report to the Radiology Section of the International Congress, held in London in August 1913, is so complete that this part of the work will be largely modelled on his lines.

Disturbances of Secretion.—The Schwartz capsule may be employed to estimate the amount of free hydrochloric acid in the stomach. "This capsule is made of gold-beater's skin of known thickness, containing 4 grammes of chemically pure bismuth and 25 grammes of pure neutral pepsin; the latter is added to hasten the digestion of the capsule, so that it will occur within five hours, and to make the time of digestion entirely dependent upon the amount of hydrochloric acid by providing an excess of pepsin. By experiments *in vitro* the time has been determined which is required to digest the capsule with fixed amounts of free hydrochloric acid. These results were found to conform to the time taken to digest these capsules in a large series of cases. The patient is given in the morning, while fasting, a test meal consisting of 200 grammes and a measured quantity of bread. The capsule is taken and observations made at regular intervals by means of the fluorescent screen, in order to see when the capsule is digested as indicated by dissipation of the bismuth."

Pathological Changes in the Form and Position of the Stomach.—While studying the changes in position and shape of the stomach itself, one must bear in mind those changes due to pressure from without. Among these may be mentioned pregnancy; tumours of the viscera, such as fibromata; cystic conditions, or tumours involving the abdominal walls. The presence of peritoneal bands or adhesions must also be considered. These may be suspected when during an examination any particular part of the organ appears to be unduly fixed, or when the whole organ is relatively higher than normal. These adhesions are a frequent accompaniment of healed gastric ulcer, inflammatory conditions of the gall-bladder, etc.

Ptosis.—The most obvious and frequent change noted in the stomach is that of ptosis. In true gastroptosis the bismuth meal is seen to fall through the stomach quickly, the lack of muscular tone allowing the food to pass rapidly through and collect in the sinus. The pylorus and œsophagus with the fundus are firmly fixed by their ligaments, and the ptosed stomach therefore increases in vertical length, the bismuth meal distending the lower portion of the stomach, while in the median part of the body the walls are approximated, the fornix being generally distended with gas. The peristaltic waves are almost entirely absent in the erect position, and show then only in the pyloric canal. They are more frequent and deeper when the patient lies down. In most of these cases a condition of atony of the stomach wall supervenes. Then great dilation may follow, though the atony may be compensated for by muscular hypertrophy. In ptosis with atony the stomach is incapable of emptying itself for six to eight hours, or even longer, after ingestion of the meal.

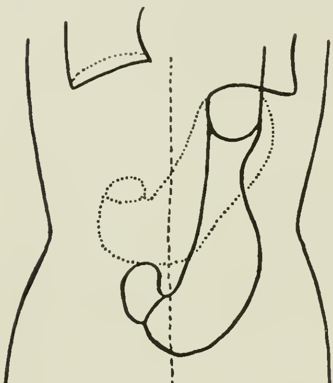


FIG. 291.—To show position of stomach in ptosis. Pylorus is also dropped. Dotted line represents the normal position.

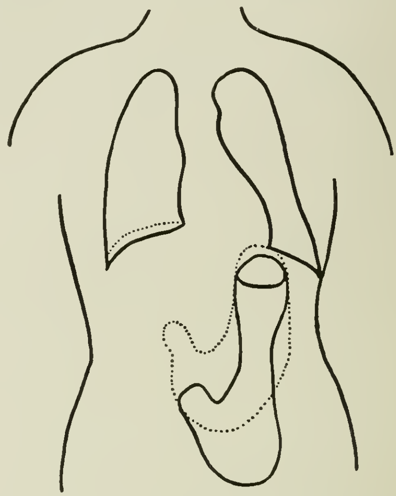


FIG. 292.—Diagrammatic representation of pyloroptosis, with some atony of the stomach.

Pyloroptosis.—This is a pronounced form of ptosis, involving the pylorus, which is often as low as the fifth lumbar vertebra.

Ulcer of the Stomach.—The diagnosis of gastric ulcer by the Röntgen method is one of its greatest advances. The extent to which the stomach wall has been involved in the pathological process influences the accuracy of the diagnosis, simple ulcer involving only the gastric mucosa being the most difficult to distinguish. Perforating ulcers that involve the muscular wall can be recognised in a much larger percentage of cases, while perforating ulcer of the callous type can be detected in the majority of cases. Chronic ulcers with or without perforation that have produced contractions, present a picture of hour-glass contraction, and are easily recognised.

Care should be taken to watch the meal entering the stomach. Hour-glass contraction can readily be recognised, and the presence of a narrow canal between the two segments is diagnostic. A large shadow in the upper segment is often clearly seen, soon a fine pencil of bismuth may be detected passing through the stricture, and later the whole of the meal may be located in the lower segment. This class of case must be differentiated from the malignant hour-glass contraction and the intermittent and pseudo hour-glass contraction. Perforating hour-glass contraction, which has not

a

b

c

PLATE LXVII.—Stomach showing Obstruction at Pylorus.

a, Stomach showing marked delay in emptying time, due to cicatricial contraction at pylorus. Diagnosis, pyloric ulcer, confirmed at operation.

b, Showing prolonged delay at pylorus. Note irregular outline and narrow channel. Diagnosis, carcinoma of pylorus, operable. Confirmed at operation, tumour excised.

c, Marked delay in emptying of stomach, narrow channel connecting stomach and duodenum. Diagnosis, cicatricial contraction at pylorus, due to gastric ulcer, confirmed at operation.

changed the form of the stomach through the contraction of scar tissue, is the most readily diagnosed ulcerative condition, except hour-glass contraction. Haudek first established their radiographic diagnosis, and has formulated their Röntgenologic symptom complex and signs as follows :

(1) *A diverticular* projection from the stomach shadow, mostly on the lesser curvature.

(2) *Movability* of the bismuth mass by palpation.

(3) *The persistence* of a bismuth shadow at a particular point.

(4) *A hemispherical* collection of gas above the bismuth shadow.

(5) The constant and marked contraction of the greater curvature of the stomach at a point opposite to the shadow, approximating in form to an hour-glass contraction.

(6) *A displacement* to the left of the pyloric portion of the stomach, especially noticeable in males, with a perpendicular outline on the right border of the greater curvature.

(7) *A retardation* of motility, so that six hours after the ingestion of the bismuth meal a large portion remains in the stomach. This residue is placed to the left of the median line when the ulcer lies high.

(8) *Antiperistalsis.*

(9) The presence of an acutely tender spot, with a sense of resistance on pressure, in the epigastrium, in the region of the left rectus muscle. This is frequently seen in ulcer of the body of the stomach.

It is of practical importance to remember that these ulcers, while occurring most frequently on the lesser curvature of the stomach, may be found on the anterior and posterior walls. During the examination, therefore, the patient must be rotated, or the tube displaced from side to side, in order to bring ulcers in these positions to the profile of the stomach shadow. Unless this is done they will be entirely hidden by the mass of bismuth in the stomach, and escape detection.

The neighbouring organs most frequently involved in perforating ulcers are the liver and spleen. When the liver is involved the shadow rises and falls with respiratory movements.

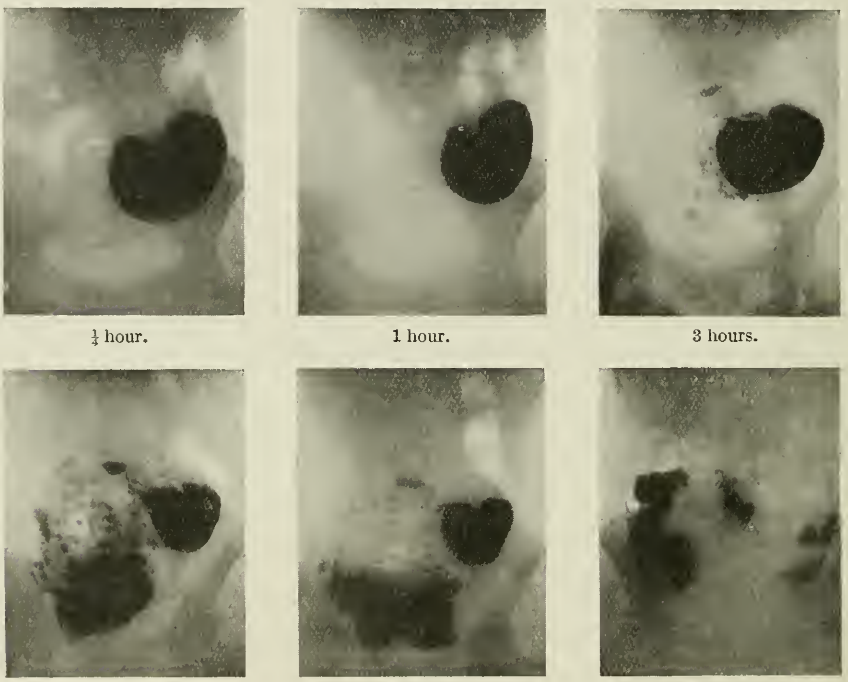
The pathological conditions met with in the stomach are numerous. and have a bearing on the behaviour of the organ when examined by the opaque meal. Of these conditions the most common is ulcer of the stomach. There are several stages of ulcer which require to be distinguished : acute ulcer, chronic ulcer and its sequelæ, hour-glass contraction, pyloric stenosis, obstruction at the pylorus due to adhesions in its neighbourhood, dilatation of the stomach secondary to pyloric adhesion stenosis, or to adhesions of other organs.

Other conditions are : malignant disease of the stomach, with or without hour-glass contraction ; alteration in the shape of the stomach resulting from lesions affecting other organs in the abdomen ; extragastric pressure from tumours or adhesions. In order to appreciate fully the diagnostic significance of these affections, it will be necessary to consider the appearances presented by each *seriatim.*

It is not possible to deal fully with the pathology of gastric ulcer, nor with the many theories which have accumulated around the ætiology of the complaint; but it is well that the radiologist should have a clear conception of the varieties met with, the common situations, and the sequelæ.

Welch, from hospital statistics, collected 793 cases, and found that 288 were on the lesser curvature, 235 on the posterior wall, 95 at the pylorus, 69 on the anterior wall, 50 at the cardia, 29 at the fundus, 27 on the greater curvature.

The Acute Ulcer.—The acute ulcer is usually small, and punched out, and the peritoneal surface is not thickened. This type of ulcer is therefore



½ hour. 1 hour. 3 hours.

5 hours. 7 hours. 24 hours.

FIG. 293.—Chronic pyloric obstruction. Cicatricial contraction at pylorus, dilatation of stomach.

the most difficult to demonstrate by radiography, *i.e.* the demonstration of the actual ulcer itself, though its presence may be suspected by the behaviour of the stomach when an opaque meal is given, viz. the rapid *movement*, emptying and hyperactivity of movement, and a high position of the organ. This is also the ulcer which gives rise to marked symptoms. It may be multiple.

The Chronic Ulcer.—The chronic ulcer is larger. It may reach an enormous size, and involve a large area of the stomach walls; it may penetrate the mucosa and invade the muscular walls, and even other organs. It may heal rapidly, or, on the other hand, no attempt at healing may occur for years. This form is the one most frequently shown by radiography, either directly or by its effects upon the stomach. It may heal in places, leaving cicatricial contractions, which cause, according to their position, pyloric stenosis, hour-glass contraction, etc.

Among the most serious changes which may result are the following:

Perforation.—This change is generally preceded by adhesions, as a result of the infiltrating inflammatory processes around the ulcer. These may be to any of the abdominal organs in close proximity to the stomach.

When perforation has occurred, the stomach contents are prevented from passing into the peritoneal cavity by these adhesions, and when an opaque meal is given, it is often possible to show the site of the perforation, its size and shape, etc.

Erosion of blood-vessels leads to hæmatemesis, and is clinically recognised.

Cicatrisation.—Superficial ulcers often heal without causing any serious damage, and are consequently not recognisable by radiographic methods.

Stenosis of the pylorus not infrequently follows the healing of an ulcer in its neighbourhood. It must also be noted that an ulcer which does not cause stenosis of the orifice may, by irritation, cause spasm at the pylorus, and produce at the radiographic examination the appearance of stenosis. This is, however, likely to be intermittent in character, and should not lead to the prolonged delay in emptying of the contents which is a constant phenomenon in obstruction due to actual stenosis. Spasm at the pylorus may also be a result of the presence of an ulcer in other regions of the stomach than the pylorus, and may cause delay in emptying. When present, this may when radiographed lead to a serious error in diagnosis. Such cases should be examined more than once, when the intermittency of spasm usually noticed should prevent an error. It is also to be noted that an ulcer or inflammatory lesions in the duodenum, gall-bladder, or intestine may also lead to a condition of spasm at the pylorus and delay in emptying. This condition has been already dealt with in an earlier paragraph.

Perigastric Adhesions.—The condition is common, and is found in as high as 5 per cent of post-mortem records. It follows ulcer, lesions of the gall-bladder, disease of the pancreas, syphilitic disease of the liver, and chronic tuberculosis. In many instances the condition is quite extensive, and has been called plastic perigastritis. It may be associated with hypertrophic stricture of the stomach and chronic plastic peritonitis. In a number of cases the pylorus may be narrowed as a result of the adhesions, or a form of hour-glass contraction of the stomach may be produced.

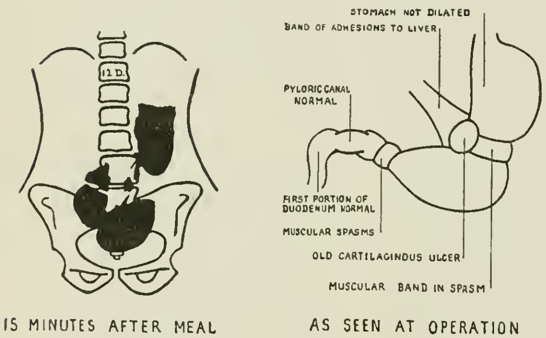
Callous Ulcers.—The most common seat of callous ulcers is upon the lesser curvature of the stomach, the contraction due to cicatricial changes after healing giving rise to a shortening of the lesser curvature. Haudek has pointed out that this leads to a dragging of the pylorus to the left, and has shown that a difference can be noted in the shape and position of the residue in the sinus and its relation to the bulbus duodeni. In perforating callous ulcers, and in florid ulcers with or without penetration, the residue in the sinus has a sharp, straight, almost perpendicular outline on the right side, with the shadow of the bulbus duodeni to the left of the umbilicus, and nearly above the sinus. In carcinoma of the pylorus the residue has a poorly defined jagged right border, while the bulbus duodeni is well to the right of the umbilicus. In uncompensated stenosis of the pylorus the residue is broader, is drawn out in the form of a crescent, and extends to the right and left of the middle line, while the shadow of the bulbus duodeni is far to the right.

Plate LXVIII. illustrates phases in the passage of the food from the stomach in pyloric stenosis.

Plate LXIX., Fig. *a*, illustrates the appearance shown by the bismuth food in a large atonic stomach, with pyloric stenosis, due to the healing contraction occurring in pyloric ulcer. Note the level upper surface of the bismuth shadow.

Penetrating Ulcer.—Penetrating ulcer of the stomach differs markedly from perforating ulcer, in that instead of the rounded diverticulum filled with bismuth and gas, there is only a slight bud or spur-like projection from the profile of the stomach shadow. The right lateral portion is of value in these cases. A variation in the technique is described by Schwartz, in which he employs a watery solution of bismuth in small quantity. It is used with the patient on the back. The patient is then turned gently first on one side and then on the other, and finally on the abdomen. This is to coat the mucosa, so that shallow ulcers will retain a small amount of bismuth when the patient stands erect. He has succeeded in this manner in locating small ulcers on the posterior wall of the stomach. The simple ulcer is the most difficult to demonstrate, and is frequently missed altogether. The florid or indurated ulcer, either with or without erosion, is also very difficult to recognise, as are also ulcers situated in the pyloric canal or in the neighbourhood. Except in rare cases of perforating ulcer, the X-ray picture is not definite. The diagnosis must be based on the obstructive signs :

a



b

FIG. 294.—Chronic ulcer at lesser curvature of the stomach (hour-glass contraction—spasmodic).
a, Radiographic appearances of stomach after complete filling of the organ.
b, Diagrammatic representation of condition found at the operation.

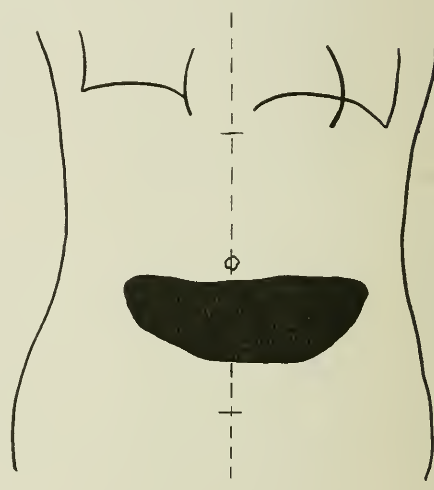
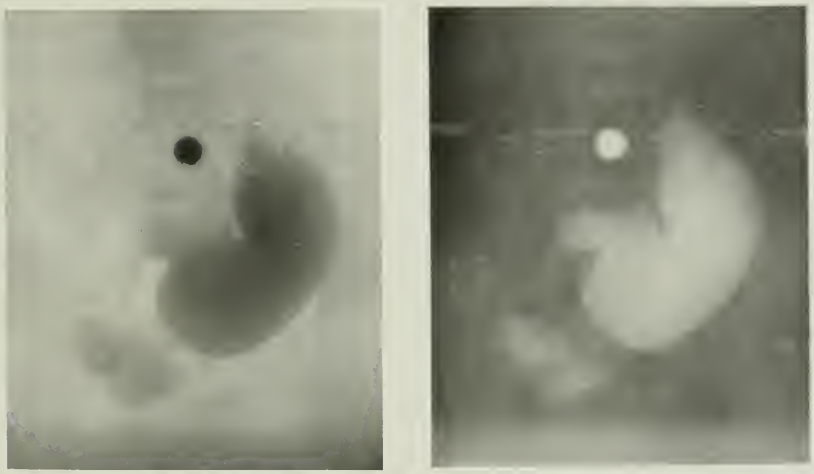


FIG. 295.—Diagram to represent a condition met with in examination of the stomach. This is typical of atony of the stomach walls secondary to pyloric obstruction.

a

b



c

PLATE LXVIII.—STOMACH SHOWING PYLORIC STENOSIS.

The stomach shows a marked degree of ptosis.
a, Marked delay in emptying caused by cicatricial contraction resulting from healed gastric ulcer.
b, Four hours after—food taken. Shows food passing along duodenum.
c, Eight hours after—food still in stomach. The organ is not now contracting well.

a

b

c

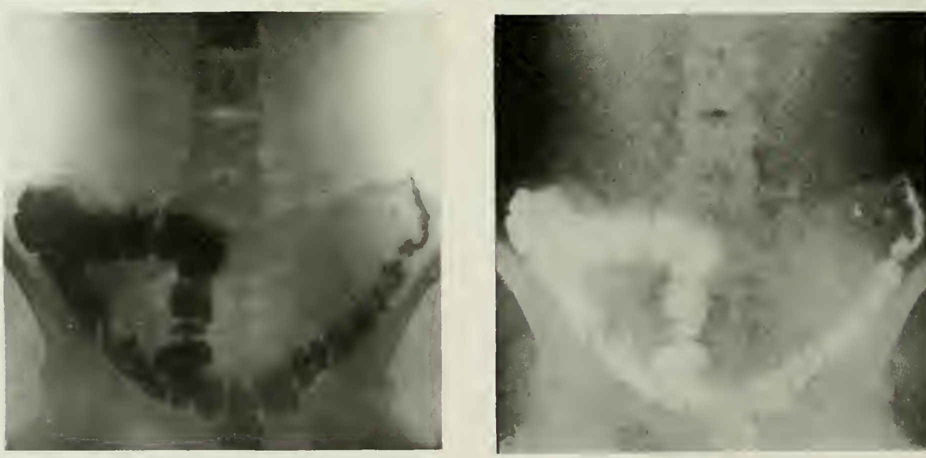


PLATE LXIX.—OPAQUE MEAL IN STOMACH AND COLON.

a, Opaque meal in stomach twenty-four hours after ingestion ; pyloric obstruction confirmed at operation.
b, Delay in stomach due to adhesions at pylorus, which was attached to anterior abdominal wall.
c, Colon from the same patient, showing a sharp bend in transverse colon, which was adherent to anterior abdominal wall, confirmed by operation.

(1) The spasm of the pylorus is more marked ; (2) there is a decrease of the motility, and a large residue of the bismuth meal is left in the stomach after six hours. This is the result of the intermittent opening of the pylorus in the presence of spasm.

If care is taken to examine the patient frequently at the time when the food is engaging in the pylorus, a small streak of the bismuth is occasionally seen entering and passing through the narrow canal. It may remain for an appreciable time in the stricture.

Congenital Hypertrophic Stenosis of the Pylorus.—X-rays have been used to determine the presence of this interesting condition. The technique requires to be modified when infants and young children have to be examined. In the former one or two drachms of bismuth carbonate may be mixed with milk, and the child fed in the ordinary way.

FIG. 296.—Congenital hypertrophic stenosis of the pylorus.

For older children the bismuth may be given in the form of a thicker emulsion, or it may be mixed with milk and bread crumbs, as for an adult, a smaller quantity being used.

C. S. Mixer, who recognises pylorospasm, describes the appearance of the bismuth shadow in these cases. Directly after ingestion, the stomach is shown distended, the bismuth being evenly distributed, and the pyloric end of the bismuth mass outlined in a prow-like rounded end. Later, bismuth begins to appear as minute dark patches in the small intestine, the amount passing the pylorus depending on the degree of obstruction. The bismuth, which at first filled the stomach, the pyloric portion being well to the right of the mid line, gradually assumes the form of a dense ball-like mass at the most dependent portion of the greater curvature near the middle line, generally a little to the left. The stomach is still distended, its outline being marked by the particles of bismuth clinging to the mucous membrane. Between its walls and the central mass is a wide air space, except where the bismuth lies in contact with the greater curvature. The pyloric end retains its prow-like shape. This condition will remain unchanged for several hours. The difference between the radiogram of true stenosis and that of cases which are classed as pylorospasm is slight. At first the two are identical; later, when the bismuth becomes ball-shaped, the exaggerated type of peristalsis is evident in stenosis, whilst it is absent in spasm.

J. L. Moore finds radiograms of great value in the diagnosis of this condition, but Holt, on the other hand, says that they may be quite misleading. This statement applies to all examinations by the opaque meal. The errors are probably those of incorrect interpretation of the conditions seen.

Pseudo Contractions of the Stomach.—These are the result apparently of various conditions which lead to a reflex spasmodic contraction of the greater curvature, with a consequent deep infolding. They must be distinguished from the true hour-glass contraction, due to disease of the stomach (simple ulcer or malignant ulcer). Repeated examinations will be necessary to determine this. The contractions are frequently not persistent, the duration being variable; in one case it may be observed only once or twice during the complete emptying of the stomach, in others it may persist for long periods, and lead to considerable difficulty in diagnosis. In doubtful cases, the only way to decide the point is to repeat the examination after an interval, or it may be desirable to give anti-spasmodic drugs hypodermically at the time of examination in order to get rid of the spasm.

Intermittent Hour-glass Contraction.—This may simulate in every detail the true hour-glass contraction. It may take the form of a contraction in the middle of the stomach, with apparently two equal portions; or the upper segment may contain all the meal with the magenblase well marked above. The greater curvature shows a marked depression in other cases. There is no retardation of motility, and there may be even an increased rapidity of emptying, the administration of atropine leading to no change in the condition. Such cases require to be examined on more than one occasion before an accurate diagnosis can be made. There is never any residue after six hours. The normal stomach picture will be obtained on one examination, and the hour-glass contraction at another time. The appearance of hour-glass contraction may be reproduced in the same patient on more than one occasion. It is possible that the condition of the colon, bound by adhesions, may be an explanation of the contraction.

Fig. 297.—Hour-glass stomach. Photograph from a post-mortem specimen. Shows a well-marked constriction, resulting from a healed ulcer. There were a number of small active ulcers in both segments of the stomach.

True Hour-glass Contraction.—There are three varieties met with: (1) *Congenital*; (2) *Non-malignant*; (3) *Malignant.*

(1) The existence of true *congenital* hour-glass contraction is doubted

by many authorities, and when it does occur it may be regarded as an anatomical curiosity.

(2) *Non-malignant Hour-glass Contraction* is generally due to ulceration of the stomach wall, with secondary cicatricial contraction, ulceration generally beginning at the lesser curvature of the stomach. Its frequency is probably much greater than was at one time supposed. The demonstration of its presence is due to the now almost universal adoption of the radiographic method in the diagnosis of disease of the stomach. Thurstan Holland analyses his findings in thirty-four consecutive cases of hour-glass stomach. He points out the frequency of the condition, and shows that the correct diagnosis in the majority of cases has been arrived at entirely from the radiograph, for in the whole series the condition had, before the X-ray examination, been suspected in two only. The sex occurrence is interesting, as in thirty-two of the thirty-four cases the patients were females. He further comments

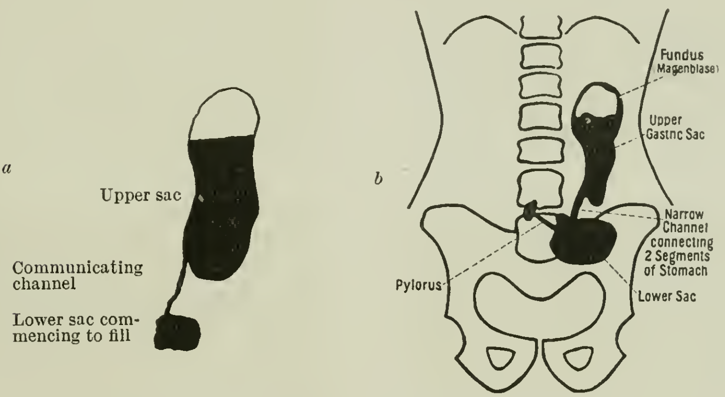


FIG. 298.—Hour-glass contraction of the stomach.
(*a*) Soon after ingestion of food. (*b*) One hour after ingestion.

on the relationship of gastric ulcer to intermittent hour-glass contraction of the stomach. These may simulate in every detail true hour-glass contraction. It may take the form of a contraction in the middle of the stomach, with apparently two equal portions, or the upper portion may contain the whole of the meal.

The greater curvature shows a marked depression in other cases. There is no reduction of motility, and there may be even an increased rapidity in emptying, the administration of atropine leading to no change in the condition.

Such cases require to be examined on more than one occasion before an accurate diagnosis can be made. There is rarely any residue after six hours, showing that there is no real obstruction to the passage of food. The usual stomach picture may be obtained at one examination, while the hour-glass will be found at another. It is possible in some cases of this condition that a colon involved in adhesions may give rise reflexly to the condition of hour-glass stomach, or there may actually be adhesions between the stomach and colon. Fig. 297 shows a post-mortem stomach, which is markedly hour-glass ; it had several small ulcers in both segments.

In Fig. 298 the constriction of the stomach in the middle of the body

FIG. 299.—Hour-glass contraction.

Four radiographs taken at intervals of two seconds ($\frac{1}{100}$ second exposure). The peristaltic wave is well seen on the walls of the upper sac. A small penetrating ulcer on lesser curvature with barium food in situ and gas bubble shown in upper part.

marks the seat of an ulcer on the lesser curvature, which by cicatrisation has led to organic contraction of the stomach. This condition has to be distinguished from spasmodic hour-glass contraction, and from that caused by new growth of the body of the stomach.

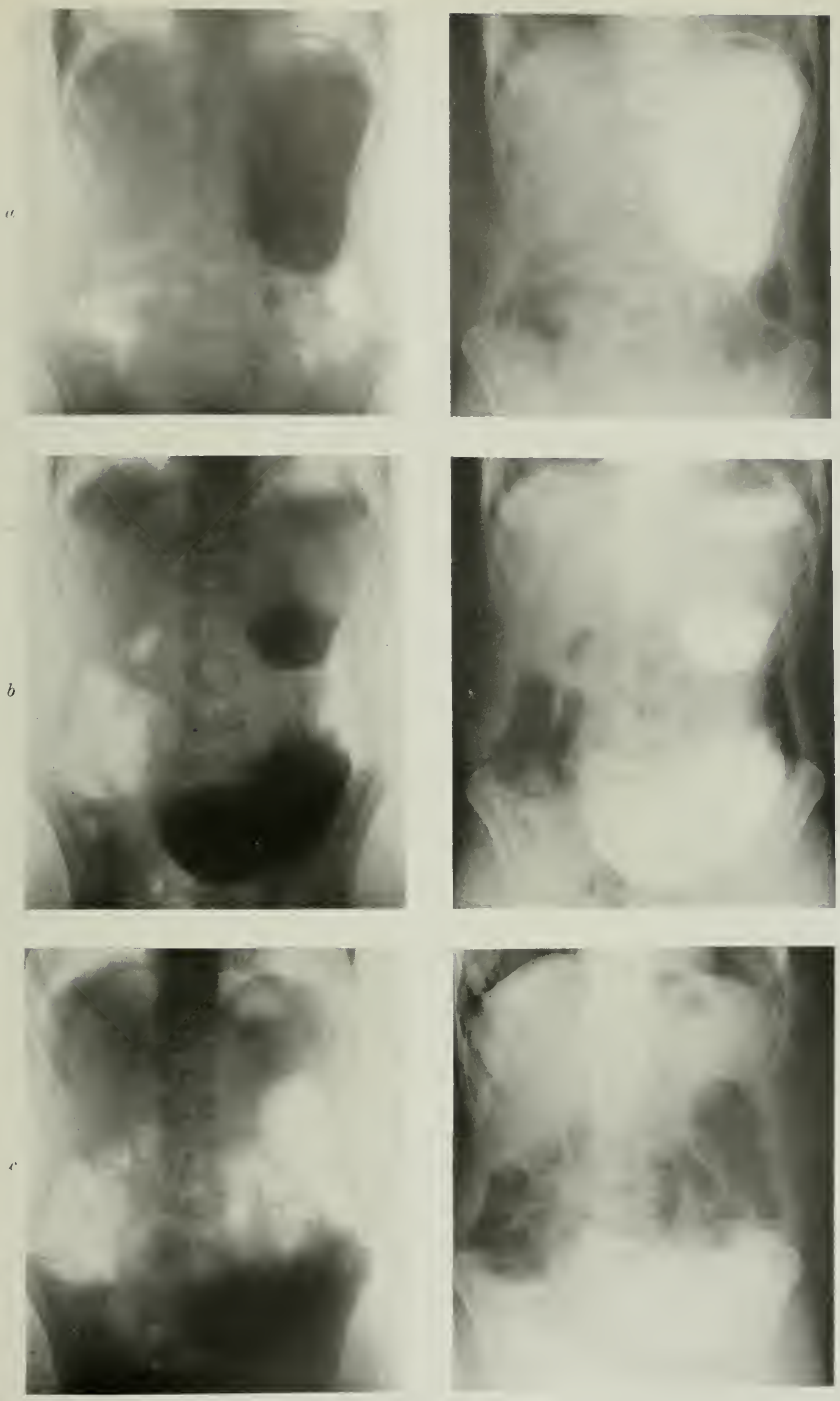


PLATE LXX.—Hour-glass Contraction of the Stomach.

a, Shortly after ingestion of barium meal. Note shape of stomach and small portion of the meal engaging in a narrow channel of communication.

b, Same stomach several hours later ; the greater portion of the meal is now in the lower sac. Upper sac still contains a portion of the food, nearly all of the meal is now in the lower sac. Eight hours after ingestion very little of the food has passed through the pylorus.

c, Radiograph taken at ten hours, and later showed marked delay in emptying time of stomach. Diagnosis, hour-glass contraction of stomach, also pyloric stenosis secondary to another ulcer.

Malignant Hour-glass Contraction.—The invasion and concentric spread of a growth in the circumference of the body of the organ results in an hour-glass form of stomach, the growth spreading in all directions, upwards, downwards, and concentrically, though the extension may not be equal in all directions. The resulting Röntgen picture is, therefore, not only one of lacunar biloculation, but also of a ragged irregularity and deficiency in the stomach shadow, which may have a funnel-shaped entrance and exit. The food on entering the stomach passes directly through the canal, if it has any degree of lumen, into the lower segment of the stomach. The emptying may not be delayed, unless the pylorus is also involved. In malignant disease the normal relations are more nearly maintained, as there is not so much displacement due to cicatricial contractions. The question of a callous ulcer taking on the malignant characteristics must be referred to. In all probability the great majority of simple ulcers remain so to the end, evidence being rarely produced to show that the malignancy has been implanted on a chronic simple ulceration. The possibility of such an occurrence renders an absolute differential diagnosis impossible in all cases.

Cancer of the Stomach.—This is one of the most important diseases for the use of Röntgen rays in diagnosis, for in no situation is the early diagnosis of cancer so essential as when it locates itself in the stomach. Taken in

FIG. 300.—Three examples of carcinoma of the stomach. (Haudek.)

conjunction with the history and the evidence of chemical examinations by means of the test meal, the Röntgen method completes the picture, and enables us to make a positive diagnosis not only of the presence of a growth, but also of its position and size, the involvement of neighbouring organs, and the possibility of an early radical operation.

Carcinoma may be found in any portion of the stomach, the most common situations being the cardiac orifice, the pylorus, with the adjoining stomach wall, and the lesser curvature of the body of the stomach. The characteristic appearance is that of a stomach shadow more or less ragged and irregular in a part of its extent, with generally a delay in the passage of the food : masses of the growth project into the shadow of the opaque food, and so cause irregularities of the shadow. All cases examined which show irregularity should be re-examined in order to confirm the diagnosis.

Welch analysed 1300 cases in which the distribution was as follows: pyloric region, 791; lesser curvature, 148; cardiac, 104; posterior wall, 68; the whole or greater part of the stomach, 61; multiple tumours, 45; greater curvature, 34; anterior wall, 30; fundus, 19.

The diagnosis by X-rays enables us to ascertain: (1) *The presence of a tumour*, (2) *position and size of the stomach*, (3) *situation of the tumour*, and its relation to other organs.

Fig. 301.—Illustrating the appearances seen in carcinoma at pyloric end of stomach. The shaded area represents the tumour.

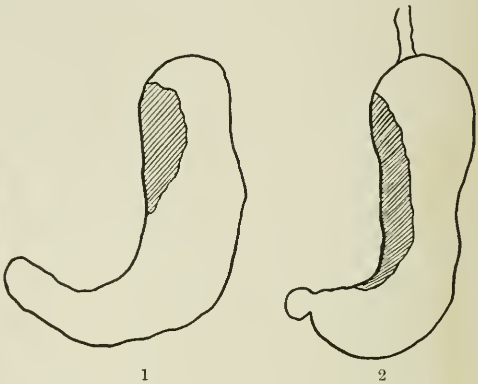


Fig. 302.—Situations of tumour in the stomach.

(1) Tumour situated near the cardiac end of the stomach. The stomach in this case contained bismuth food twenty-four hours after ingestion. There was no pyloric obstruction found at the operation.

(2) Large carcinoma involving lesser curvature. The stomach emptied rapidly in this case. A large tumour was found converting the lumen of the stomach into a funnel-shaped channel.

Position of the Tumour.—When situated in the pyloric portion there may be decided evidence of a narrowing of the pyloric canal, accompanied by dilatation and tortuosity of that part of the stomach. In rare instances an irregular outline of the tumour may be shown. The position of the stomach is generally higher in the abdomen than in the case of pyloric obstruction due to chronic ulcer. As referred to elsewhere, the degree of dilatation of the stomach in malignant disease is less marked, partly because of the much shorter history and from the inability of the patient to take food.

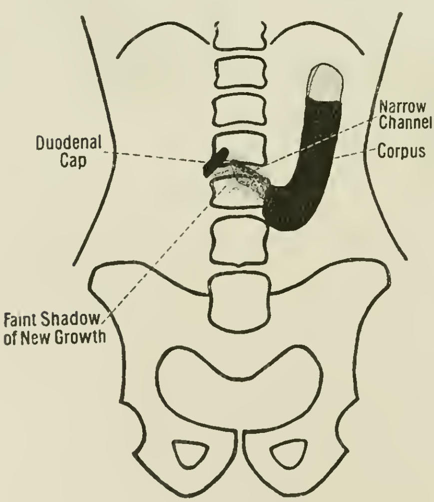


Fig. 303.—Obstruction at pylorus due to new growth. Operable.

Carcinoma of the Cardiac End of the Stomach.—This is a condition which may also involve the lower end of the œsophagus. A stricture may be found at the cardiac orifice, or a complete occlusion of the opening. These may be demonstrated by the use of the barium meal.

The presence of a tumour of the stomach may be readily shown, or it may be suspected by the variations in the behaviour of the organ after the bismuth meal has been taken. In some instances when the growth is situated at the pylorus, there may be a considerable delay in the emptying of the stomach. This may be of some duration, but as a rule it does not become so marked as in the case of chronic ulcer at the pylorus. The latter is more protracted in its course. There may be a history of several years' duration. The degree of dilatation is consequently more marked in the case of chronic ulcer. Narrowing of the pyloric canal is present in both conditions, but the narrowing due to new growth is generally more irregular, and a faint shadow around the bismuth shadow in the narrow canal may give an indication that the case is one of new growth. As a result of adhesions round the ulcer, the pylorus tends to become fixed. This may occur in both diseases.

Carcinoma of the lesser curvature may show its presence by an indentation of the bismuth shadow caused by the bulging mucous membrane and growth protruding into the lumen of the organ.

Carcinoma situated at the cardiac end of the stomach may by partial occlusion of the œsophageal opening lead to a marked contraction of the stomach. The food getting into the stomach in small quantities gives a much less definite filling phenomenon than the normal.

New growth which invades the greater curvature of the stomach wall may give a very small narrow lumen, with an ill-defined irregular bismuth shadow. In a limited number of cases the stomach empties rapidly.

New growth which involves the greater portion of the stomach wall some distance from the pylorus, will, by an interference with the nerve reflexes and alterations in the peristaltic wave, lead to a delay in emptying which may give rise to the erroneous impression that the pylorus is affected, and that an actual stenosis is present.

One of the most useful aspects of radiographic methods in connection with stomach diagnosis is the possibility of determining the size of the growth and its effects upon the motility of the organ.

Malignant disease in other organs may press upon the stomach, and so give an erroneous impression that this organ is involved; in a particular instance the stomach at operation proved quite free from growth. Infiltrating malignant disease results in a thickening and hardening of the stomach walls, producing a form of stomach like the hypotonic. Peristalsis is wanting, sometimes to a marked degree, in the portion of stomach wall involved, and the whole stomach may be converted into a rigid canal of small calibre, through which the bismuth meal flows quickly into the duodenum. In carcinoma of the pylorus the defects in the stomach shadow vary in form with the extent and position of the tumour.

Abdominal Adhesions.—The demonstration of adhesions of stomach and bowel to other parts is very helpful to the operating surgeon, showing in many instances the need for operation and indicating the site of the lesion.

Stricture of the Bowel may be likewise located, and time saved at the operation. This is a most important point, because without this assistance the surgeon may operate at the wrong point, and time be lost which is all-important to the patient. We have seen instances in actual practice where the exact location of the morbid condition might have been of the greatest possible use. It may also be possible, when a stricture has been located, to determine whether the growth is fixed or free, this being an important point in estimating the possibility of complete removal of a growth.

The demonstration of a lesion which is beyond the reach of surgery may sometimes save the patient from an operation which not only fails to cure, but may even aggravate the distress and discomfort due to the disease.

Examination of the Small Intestine

Bismuth food passes so rapidly through the small intestine that the determination of a peristaltic wave is a matter of great difficulty. With the exception of a small mass in the bulbus duodeni, and the collection of masses in the convoluted portion of the ileum, little is seen in normal cases, but rapid radiographs show small flakes scattered throughout the duodenum, jejunum, and the upper portion of the ileum. It is very important to be able to demonstrate the duodenum in the normal condition and in morbid conditions due to various causes.

The Duodenum.—The duodenum comprises the first nine or ten inches of the small intestine. It passes from the pyloric end of the stomach, at first backwards and then downwards, until it disappears behind the transverse colon. Passing to the left of the spine it ascends for a short distance, and at the level of the second or third lumbar vertebra passes into the jejunum, forming a sharp bend forwards and downwards, which is named the duodeno-jejunal flexure. It makes a curve round the head of the pancreas. The first portion is nearly horizontal and is free and movable like the stomach. The second or middle portion descends and is about 3 inches in length. The third or inferior portion is the longest of all; after crossing from right to left of the spine it ascends to end in the jejunum, opposite the second or third lumbar vertebra.

The opaque meal passes rapidly through the duodenum, in from 25 to 60 seconds. Special technique is necessary to show successfully the duodenum in the normal subject, departures from the normal being more easily shown. Observations on the duodenum may be made with the patient standing up or lying on the X-ray couch. It is better to examine the patient in the upright position, centering the tube over the pyloric end of the stomach. A slight degree of lateral rotation of the patient throws the duodenum well into the field of vision, and on screening, the bismuth is seen throughout its whole course along the duodenum. Jordan describes a method by which he claims to be able to demonstrate the duodenum in nearly every case. He uses a preparation of bismuth carbonate with sugar of milk, and examines the patient in the right lateral position upon the X-ray table. His special technique for the examination of the duodenum is as follows:

Method of Examination for Intestinal Stasis

The patient takes his usual breakfast. About one or two hours later he comes for his first examination.

An emulsion is prepared consisting of bismuth carbonate, 4 oz. ; sugar of milk, 1½ oz. ; water in amount sufficient to make an emulsion which is not thick.

The whole drink makes less than a tumblerful. In the case of big subjects, 5 oz., or even 6 oz., of bismuth carbonate are given, with a correspondingly greater amount of sugar of milk and water ; even this makes no more than a tumblerful. The water should not be quite cold, especially in winter. I have not had a single case in which this dose has produced the slightest untoward result.

The sugar of milk in this " standard meal " has a threefold function : (1) to make a satisfactory emulsion, (2) to increase the bulk of the meal, and (3) to make the meal pleasant. In some cases it has a mild laxative effect.

The patient is first examined upright on a revolving saddle seat with canvas back. The chest is examined, first in the anterior view, and then in the right anterior oblique view. While in this position (R.A.O.) the patient begins to drink the bismuth emulsion, and its course down the œsophagus is well shown ; if this appears normal, and the bismuth begins to enter the stomach at once, the patient is swung round to the anterior position, and the level of the great curvature of the stomach is noted as the first portions of bismuth reach it. The final level of the great curvature is lower than usual, the difference being due to the weight of the bismuth.

After the vertical examination the patient is examined on the couch—supine, supine after lying on the right side, prone. All details regarding the size, shape, and position of the stomach and duodenum may be determined at this examination, and accurate observations may be made of the motor activities of these organs. Subsequently the bismuth passes through the small and large intestines, and enables them to be studied to great advantage.—*B. M. Journ.*, Nov. 22, 1913.

Duodenal Ulcer.—This may vary in character from the simple to the perforating. In superficial ulcer the emptying time of the stomach is normal or decreased in contrast to the delayed emptying in cases of gastric or pyloric ulcer, which produce a spasm of the pylorus, the stomach generally having the hypertonic form. Penetrating ulcer of the duodenum is less frequent, and in addition to the symptoms of superficial ulcer has the characteristic diverticulum outside the normal shadow of the duodenum, which persists as a small bismuth residue after the duodenum is empty. The bismuth shadow is therefore more marked in duodenal ulcer, because a characteristic of all ulcers of this part is the retention of the opaque chyme for a longer period than normal, as the result of a mild stasis due to spasm at the duodeno-jejunal junction.

The accurate diagnosis of duodenal ulcer by means of the opaque meal is one of the most difficult problems which the radiologist has to investigate. Combined with a careful consideration of the history and physical signs it may be possible to indicate that such a condition exists. The evidence provided is not always conclusive, and often leaves room for doubt after repeated and exhaustive examination. It is easy to understand why such conflicting and inconclusive evidence may accrue when we consider the duodenum as part of an organ which has associated with it other organs in close proximity, having a nerve supply common to all, and liable to be disturbed by lesions other than ulcer of the duodenum, situated elsewhere in the immediate or even remote vicinity of the duodenum. Thus it is not uncommon to find alterations in the behaviour of the duodenum caused by a lesion in the region of the appendix, or in the gall-bladder, stomach, or other organ.

The particular form of disturbance may cause symptoms simulating those of duodenal ulcer, and in some instances may cause the rapid movements in the duodenum and appearances indistinguishable from those of ulcer itself. Spasmodic contraction arising from reflex irritation may on the other hand lead to delay in the passage through the duodenum, leading to a marked delay in the actual emptying of the stomach, or the presence of an early growth in the duodenum may at first cause symptoms of irritation. Later, however, when the growth has increased in size, symptoms of obstruction will arise. Moreover, a new growth may ulcerate, and in this case a complication of symptoms and signs might be expected which will give rise to considerable difficulty in diagnosis.

FIG. 304.—Opaque meal in ileum and cæcum, five hours after ingestion. Stomach was completely emptied. Note the contracted ileum entering cæcum, dilatation behind the contraction, and stasis of food in small intestine. Figs. 304 and 307 being reproduced from positives the position of the cæcum is reversed.

A simple acute ulcer of small size will give rise to symptoms of irritation, activity of the duodenum, and rapid emptying of the stomach. The simple ulcer need not necessarily give any obstructive signs when the opaque meal passes through the duodenum other than those of irritation and rapid emptying of the stomach contents. A good deal will depend upon the technique employed, the duration of the exposure, etc. With the long exposure of a few years ago it was possible to determine the delay in passage through the duodenum when it was of long duration, *i.e.* in an obstructive lesion the contents of the organ could be seen in these cases. The movements of the duodenum can be observed on the screen, and this method therefore has a definite value in the diagnosis of the lesion. Observations should be made on the behaviour of the duodenum in all cases. The screen method possesses the additional advantage of enabling the operator to obtain radiographs of the parts where the signs are likely to be of value.

An observer who has been in the habit of interpreting from plates obtained by long exposures must be on his guard when using rapid exposures for the first time; owing to the rapidity of the exposure the whole duodenum may be seen filled with food, similar to pictures obtained with longer exposures when an obstructive lesion is present, and this might lead him to make a wrong diagnosis.

With very rapid exposures the whole of the duodenum may be shown filled with the opaque food. Observations made on the screen, particularly with regard to the time taken by the food to pass through the duodenum, should be sufficient to prevent such a mistaken impression. The serial radiograms will be found useful in this connection, for it may be possible to show the passage of the food and the time taken for a portion of it to pass through.

The appearances presented by the " duodenal cap " may be taken as an indication of the presence of an abnormality. Persistent deformity is in favour of a chronic lesion in the first part of the duodenum ; but it is extremely difficult to distinguish between a lesion of the pylorus in contradistinction to one in the duodenum. When a persistent deformity is present the question arises as to its exact nature, whether it is a chronic ulcer of the pylorus or first part of the duodenum, or a new growth of the pylorus. In the latter instance much will depend upon the nature of the deformity, for a growth may cause an invagination of the opaque food shadow into the substance of the shadow caused by the duodenal cap.

Diverticulation of the shadow at the periphery of the shadow when of small size is in favour of ulcer of the duodenum of the penetrating type. A large diverticulation of the second or third part of the duodenum with smooth, well-defined edges favours ulcer. Case has recorded several instances of this kind.

The duodenal cap may show very little deformity, but the connection between the stomach and the pyloric canal may be very irregular and narrowed. Such an appearance is strongly suggestive of cicatricial contraction secondary to chronic pyloric ulcer. An indefinite irregular shadow outside the narrow streak of opaque food is in favour of new growth of the stomach involving the pyloric canal.

A persistent residue in the duodenum in the intervals between the peristaltic waves which pass from the stomach to the duodenum is an indication of a chronic lesion in the duodenum. A shadow persisting for some time after the stomach has completely emptied is almost conclusively diagnostic of the presence of an ulcer, chronic in nature, but it is not easy to determine whether it is simple or malignant.

Tumour or cyst of the head of the pancreas may by pressure lead to alterations in the appearance of the duodenal shadow which may be very misleading. If the radiologist relies on the screen method alone, he will in course of time, and after the examination of many cases, arrive at a stage when he will be able to indicate with a large percentage of accuracy the nature of the lesion. By combining this method with the production of radiographs showing the lesions, he will have valuable evidence to support the diagnosis. The ideal method is combined radioscopic and radiographic observations. In regard to the latter there is no doubt that, if the evidence is to be of any value, the serial radiographic method must be employed.

We owe this development of the technique primarily to Gregory Cole, who has shown its value in a number of cases. Pirie and others have also demonstrated the value of this method.

Serial radiography, however, involves the investigator in considerable outlay for elaborate apparatus and the use of a large number of plates before he can obtain evidence of much value. For moderately slow movements of the duodenum the apparatus shown in Figs. 106, 107 will be found useful. Case has shown the value of stereoscopic radiography in these conditions. For such work the plates should be changed at the rate of two plates in one second if sharp radiographs are required. When the movements of the stomach and duodenum are very rapid the plates must be changed more rapidly. Six or more plates in a second will be found a useful rate.

The Jejunum and Ileum.—These may be subject to ptosis when a general viscero-ptosis is present, though this is not common. Dilatation

Fig. 305.—Radiogram showing opaque meal in the stomach, jejunum, and ileum. Exposure $\frac{1}{100}$ of a second.

of the ileum may be the result of an obstruction at the ileo-cæcal valve or in its vicinity, when there is a delay in the passage of food to a marked degree. Malignant or inflammatory strictures may be shown, while the ileum may attain to a diameter equal to that of the colon, the obstruction producing these changes being generally chronic in its nature, and the result of malignant or tubercular disease, or of adhesions or contractions due to chronic

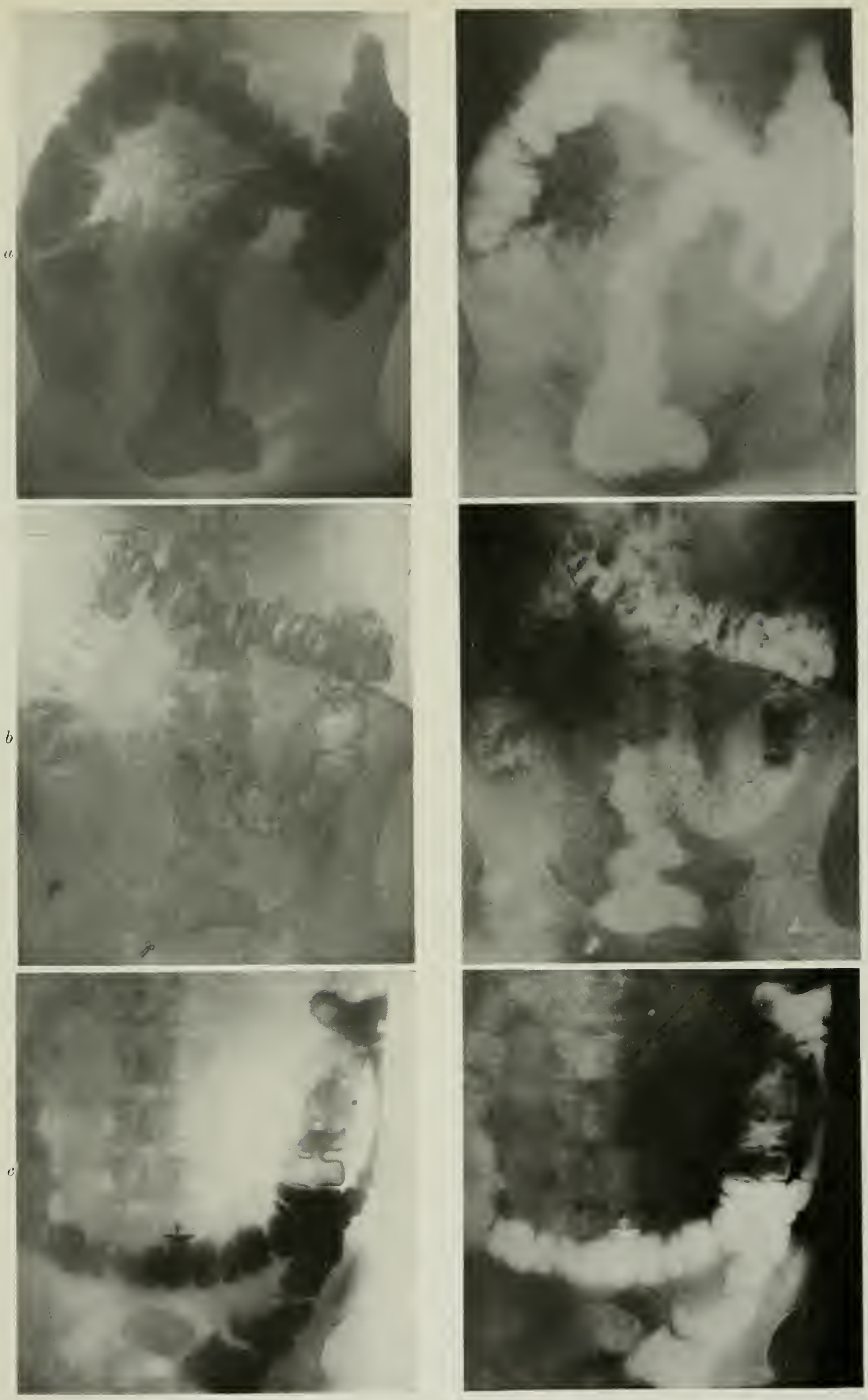


PLATE LXXI.—OPAQUE ENEMA IN COLON.

a, Bismuth enema, showing rectum, pelvic colon, sigmoid flexure, splenic flexure, transverse colon, hepatic flexure, and caecum. *b*, Same after partial evacuation. The two plates (*a* and *b*) were taken in the horizontal position ; when the patient assumed the vertical position the transverse colon formed a distinct loop with the convexity towards the pelvis. *c*, Opaque food in colon showing marked delay in descending colon. From a case of obstruction of the colon on left side, thought to be due to new growth. At operation the colon was found to be stretched over an enlarged kidney, which contained fluid. The appearance of the narrowed lumen of descending colon simulated a stenosis of the bowel.

appendicitis, or other inflammations of the cæcum and colon. These kinks

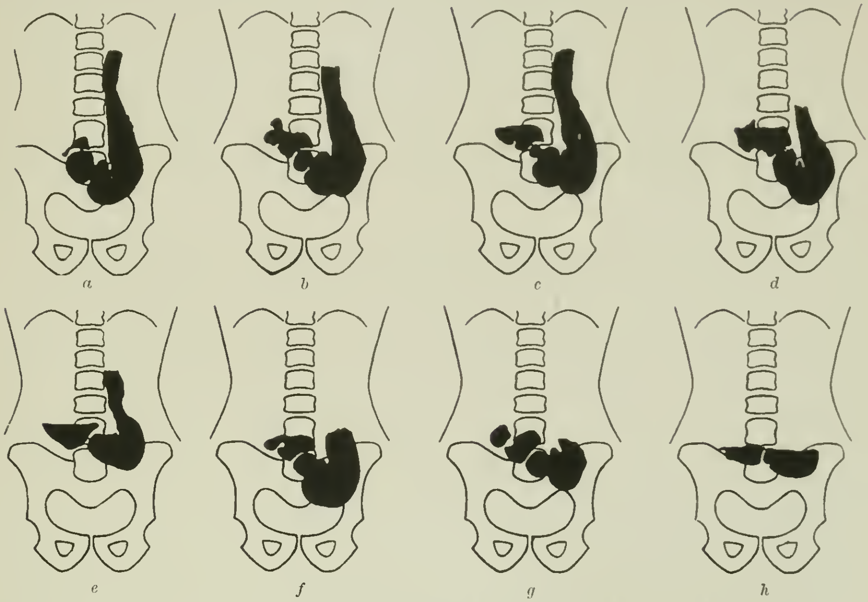


FIG. 306.—Illustrating stages in the emptying of a stomach with an abnormality at the duodenum (duodenal ulcer).

a, *b*, *c*, and *d* taken at short intervals; *e*, *f*, and *g* at longer intervals; *h*, seven hours after.

have been described by Sir Arbuthnot Lane, and demonstrated by Dr. Jordan by means of the bismuth meal. It is worthy of note that an ileal kink can be demonstrated in one position while in another it is not shown. These kinks should always be shown with the patient in the erect position where possible. In a true kink the intestine should be distended on the proximal side of the kink, and there should be definite evidence of narrowing at the point of obstruction. Figs. 304 and 307 show a condition of ileal stasis which was definitely diagnosed by the radiographic examination. The case was sent as a doubtful condition of appendix, with a suggestion that the condition was due to the presence of gall-stones; the physician in

FIG. 307.—Same case as Fig. 304 at a later stage, ten hours after ingestion. The cæcum contains more of the food. The contraction is still seen at the entrance to cæcum, and there is a marked degree of dilatation and stains in small intestine.

Diagnosis: adhesions in neighbourhood of ileo-cæcal valve.

attendance suspected adhesions in the region of the appendix. The X-ray examination revealed a condition of ileal stasis, which showed definitely in examinations lasting over several hours. A positive diagnosis of obstruction due to adhesions was given. The surgeon who operated reported as follows :

" The ileum was kinked by a fibrous band 4 to 5 inches from the ileo-cæcal valve in the position depicted by the skiagram. The gall-bladder was quite free."

The Examination of the Vermiform Appendix

The appendix is frequently the seat of chronic inflammatory changes, which may give rise to reflex symptoms at other parts of the alimentary tract. Thus it is not at all uncommon to find changes in the behaviour of the stomach and duodenum, particularly in the rate at which food passes through these structures ; also, various spasmodic contractions may be directly the result of disease located in the appendix. Adhesions in the region of the cæcum and colon may be the result of repeated attacks of inflammation in the appendix. It is therefore of considerable importance in all cases of suspected disease in the alimentary tract to be able to determine more or less definitely the condition of the appendix.

Fig. 308.—Opaque food in appendix.

The opaque food given for the examination of the stomach and intestine finds its way into the appendix. It has been found that barium, when mixed with sour milk, more readily passes into the lumen of the appendix. When the fluorescent screen is used and the region of the appendix is palpated, the appendix can be seen, and in a number of cases the condition of the structure may be determined. In this way it is also possible to determine whether the cæcum is bound down by adhesions.

It is claimed that by careful technique the appendix can be outlined in eight cases out of ten. It is possible to ascertain accurately the size, shape, and position of the appendix, the presence of kinks, or adhesions to other structures.

The best times at which to examine the appendix are six to eight hours after ingestion of the opaque food and twenty-four hours after. After six hours the head of the barium column should be halfway across the transverse colon, the cæcum should be well filled, and the appendix outlined. The patient should be in the supine position on the table, the screen being on the abdomen. The region of the appendix is gently massaged with the protected hand, or, better, by the use of a large wooden spoon. The cæcum and colon are displaced upwards ; when food enters readily the whole of the appendix should show. If the lumen is in places contracted the narrowing will show. When the structure is occluded near its base then the food does not enter at all.

All cases should be carefully scrutinised to determine if possible the condition of the appendix. Many obscure abdominal conditions may be traced in this way to the appendix, which will probably be found to be in a state of chronic inflammation.

Examination of the Large Intestine

The large intestine is divided into (1) cæcum ; (2) ascending colon ; (3) hepatic flexure ; (4) transverse colon ; (5) splenic flexure ; (6) descending colon ; (7) sigmoid flexure (pelvic colon) ; (8) rectum. The anatomical relations of these parts should be clearly understood.

The cæcum is that portion of the colon which lies below the ileo-cæcal valve. It is almost entirely surrounded by peritoneum, and, being freely movable, it may consequently vary in position in different subjects. It may be found in the pelvis or displaced upwards. The appendix is sometimes seen filled with bismuth, and may be the seat of concretions or foreign bodies. Pus, the result of an inflammatory process, may occasionally be seen.

Fig. 309.—Opaque food in the intestines of a child, showing irregular position of colon.

The ascending colon extends upwards and backwards and reaches nearly to the liver, where the hepatic flexure forms a more or less acute angle.

The hepatic flexure, together with the first portion of the transverse colon, is frequently ptosed, drawn forwards and downwards ; but this condition need not necessarily give rise to symptoms.

The transverse colon extends from the hepatic flexure to the splenic flexure. It varies greatly in position, frequently forming a well-marked loop reaching down into the pelvis. The ascending and transverse colons may be entirely in juxtaposition when the latter is ptosed, adhesions sometimes binding the two together. The transverse colon forms a tense band around the greater curvature of the stomach, the *latter* third of the transverse colon rising almost perpendicularly to the splenic flexure, where it forms an acute angle with the descending colon. It is often difficult to differentiate the one from the other by the ordinary radiograph. Stereoscopic radiographs are useful when doubt exists as to the condition present.

Fig. 310.—Dilatation due to obstruction at pelvic colon. Note the enormous distension of the descending transverse colon.

The splenic flexure is firmly held up to the diaphragm by a strong ileo-colic ligament.

The descending colon extends from the splenic flexure to the brim of the pelvis.

The sigmoid flexure is variable in shape, length, and position, as it is attached by a mesentery which varies in length.

The rectum is the most distensible portion of the colon.

Chronic constipation is a condition which frequently calls for radiographic examination. With some individuals it involves observation on the case for three or four days. The colon is frequently low in the pelvis, and it may be bound down by adhesions.

Diverticulitis of the Colon.—This condition is sometimes characterised by a palpable mass in the left lower quadrant, due to a peridiverticulitis with its mass of inflammatory tissue. Leonard and George state that the important diagnostic factor is the prolonged retention of the opaque substance in the diverticula. Shadows may persist for four or five days after the meal. The X-ray picture is characteristic. After the expulsion of the bulk of the meal, there may be found in the region of the sigmoid and descending colon numerous discrete round shadows about the size of a pea. These are due to small portions of the bismuth meal remaining in sacculations of the bowel. Great care must be exercised in the differential diagnosis between this condition and that of early new growth. Repeated examinations may be necessary to determine the correct diagnosis. The two methods should always be used : (1) The ordinary opaque meal ; (2) the barium or bismuth enema.

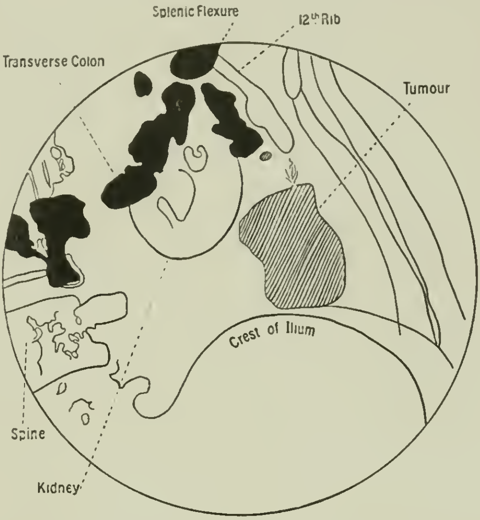


FIG. 311.—Diagram to illustrate a case of chronic obstruction of the colon due to new growth.

Tumours of the large intestine may cause partial or complete obstruction of the bowel. The double method of giving bismuth by the mouth and injecting the bowel from below is useful, the screen examination being useful when the latter method alone is employed, because we can watch for the point of stricture. Plates may be taken to confirm these observations.

Intestinal Stasis.—Jordan adds to the knowledge of intestinal stasis. He associates ileal stasis with a distended duodenum, especially in its first part, and employs a special technique to demonstrate this condition. The jejunum is found to be pulled down vertically, forming a sharp kink with the fixed end of the duodenum. He ascribes this to the direct result of gravity upon the overloaded lower ileal coils. The obstruction produced by the duodeno-jejunal kink is sometimes increased by tension of the first few inches of the jejunum.

FIG. 312.—Same case as Fig. 310, showing distension of colon by gas.

Hertz has never observed true stasis of the duodenum, except in cases of organic obstruction, and to a less extent in extreme gastroptosis, in which a kink may occur at the point where the duodenum is fixed. He is convinced that kinking plays no part whatever in the ætiology of duodenal ulcer ; nor does he believe that ileal kink is of any importance in the causation of simple constipation. He shows that all cases of constipation fall into two groups :

(1) Delay in the passage through the colon, defæcation being normal, " intestinal constipation."

(2) Dyschezia, in which the passage through the colon is normal, but defæcation is inefficiently performed.

Foreign Bodies in the Alimentary Canal

Patients are frequently sent for the determination and subsequent localisation of foreign bodies in the alimentary canal. As it is impossible to indicate in what positions they may be found, an examination of the entire tract is necessary, and the technique will be described in some detail. The foreign bodies most frequently met with are (1) coins, (2) metal toys, (3) pins, needles, safety-pins, (4) nails, (5) teeth and artificial plates, (6) hairpins, (7) enteroliths and gall-stones, (8) hair-balls.

The whole alimentary tract from the pharynx downwards must be examined, especially in children. For the pharynx and œsophagus the lateral position gives the best result. It is often difficult to locate the precise position of foreign bodies in the stomach. In doubtful cases a small quantity of bismuth food may be given, and the position of the foreign body in relation to the stomach shadow determined. When the foreign body has been located in the stomach, the question is raised as to whether it is likely to pass through the pylorus ; the necessity, or otherwise, of operation is often decided by the radiograph, and depends to a large extent on the nature of the foreign body and the presence of urgent symptoms. A foreign body which causes no symptoms and no irritation may lie in the stomach for weeks and ultimately be passed. The passage of sharp-edged or pointed bodies may be greatly facilitated by administering small pledgets of moistened cotton wool. The most usual spot at which to find a foreign body blocking the intestine is the ileo-cæcal valve. When a foreign body has been located in the alimentary tract the patient should be screened and radiographed at regular intervals. The body is thus kept under rigid observation, and should an operation become necessary it can be conducted with the least possible delay. Stereoscopic radiographs taken immediately prior to an operation, or the use of X-rays at the time of operation, when the fluorescent screen may be used from time to time, will be found useful as a guide to the surgeon. By the former method the object may be located with fair accuracy ; by the latter method the operator may be able to guide his instruments to the foreign body. Work of this special character requires to be carried out in the dark under aseptic conditions. The top of the couch must be made aseptic and the fluorescent screen be one that can be sterilised.

PLATE LXXII.—FOREIGN BODY IN THE ALIMENTARY CANAL.

This radiograph was taken with a single impulse exposure. The patient, about five years of age, was lying on the couch and the exposure was made while the child was moving.

A halfpenny in stomach. Note the detail in the abdomen, particularly the outline of liver and kidneys. In the radiogram the coin was enlarged about one-third, showing that it was situated at some distance from the plate. The coin was situated in the stomach toward the pyloric end.

THE X-RAY EXAMINATION OF THE URINARY TRACT

Radiography has now attained to an important position in the examination of the urinary tract. From a diagnostic point of view the information it gives is of the highest importance. Every case of suspected disease should be thoroughly examined before surgical interference is decided upon. In cases of suspected urinary calculus it is of great service in determining (1) the presence of a stone ; (2) its position and size ; and (3) the prognosis and treatment of the particular case, which are largely determined by a correct interpretation of the radiographic examination. It is, however, not only in cases of calculi that the use of radiography is helpful. Tuberculous disease of the kidney, ureter, and bladder may be demonstrated, and in other diseases of the urinary tract the use of X-rays may be helpful. Tumour of the kidney and bladder can be shown ; cystic disease of the kidney is sometimes demonstrable ; while it may be possible to show chronic cystitis when phosphatic deposits occur in the bladder. Hypertrophy of the bladder and other conditions present themselves for consideration, when an exhaustive examination of the organ is required.

Technique

A thorough examination of the urinary tract should be undertaken in all cases that come up for diagnosis. If stone in the kidney is suspected, it is not sufficient to examine the suspected kidney alone ; the whole tract should be systematically gone over. There are several points which are of the greatest importance in carrying out a thorough examination of the regions suspected.

A. The preparation of the patient is the first item for consideration. In all cases the patient should be prepared in the same manner as when an operation is contemplated. The bowels should be thoroughly cleared the evening before the examination, and a large enema should be administered just before the patient comes to the X-ray room. The selection of a purgative is of importance. Where possible, a vegetable purgative should be employed in preference to a chemical one, as the latter may cause shadows in the bowels, superimposed over the various parts of the urinary tract. This may not appear to be of any importance, but we have to bear in mind that the cause of the trouble may be a very small calculus in the ureter, and if it is to be shown, it is of the greatest importance that there should not be any conflicting evidence in the nature of shadows cast by small crystalline bodies in the intestines.

B. Examination of the Patient.—There is considerable latitude in the choice of a position for the examination of a patient suspected of having a stone in the urinary tract. It will be well to describe the commoner methods of examination, and then leave it to the operator to use the one he is best acquainted with.

Screen examination of the patient should always be done as a matter of routine. If the patient is placed face downwards on a couch with the tube underneath, it is possible to examine thoroughly the whole region. The fluorescent screen is placed on the patient's back, and by moving the tube about underneath the table, both kidneys, ureters, and bladder may be carefully examined. By this method of examination the majority of stones may be seen, also the size and position of the kidneys, the motility of the organs during respiration, and the size and position of the bladder. In some cases it may be useful to distend the bladder with sterile water before commencing the examination. In cases of suspected ureteric stone, an opaque catheter may be placed in the ureter from the bladder, and a stone may be located by this method. Before removing the patient it is well to take a series of plates in the position in which the screen examination has been conducted. This is useful as a permanent record of the screen examination. In particular cases a tracing may be made of the exact appearance of the parts under examination. In these circumstances a large plate may be employed. Should it be desirable to radiograph particular areas in this position, the tube is centred under the particular part, the diaphragm is closed down to a suitable aperture, a plate is placed on the back, pressure applied, and the exposure made.

With a rapid exposure movement of the organs due to respiration need not interfere with the result, but when longer exposure is necessary some form of compressor must be employed, such as a large air cushion under the patient, and pressure from above on the plate sufficient to steady the parts, in order to get a good radiograph.

The second method employed for the examination is to place the patient on his back; the plate is placed under the region required, and the tube is operated from above. In this method the screen examination is not possible, and therefore we have to depend entirely upon the examination of negatives so obtained. Here it is necessary to examine the whole tract in sections. The employment of some form of compressor is of value in this method. Any compressor which steadies the parts and arrests respiratory movements is sufficient for the purpose. The table may either be used with the tube below the patient for screening and for the taking of radiographs, with a compressor upon the plate over the part to be examined; or by turning the patient on the back, the plate can be placed underneath, and the tube-holder with a large extension tube brought down on to the abdomen. A thick pad of cotton wool may be used to compress still further the abdominal contents, this also serving the further purpose of minimising the inconvenience of great pressure. Many elaborate forms of apparatus have been designed;

the best is that introduced by Dr. Albers Schoenberg and modified by Scott. Figs. 313 and 314 show the essential parts of the apparatus, and its use in practice. It is possible by this method to get small accurate pictures of the kidneys, bladder, and ureters. A later improvement of this compressor is the addition of a stereoscopic movement to the apparatus, thus enabling stereoscopic pictures of the urinary tract to be taken.

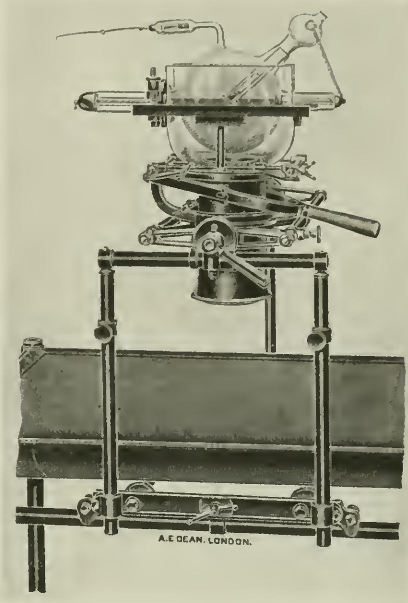


FIG. 313.—The Scott compressor.

In all cases it is important so to compress the parts that a good radiograph is obtained with long or short exposures. The shorter the exposure the better is the result. Where possible, the patient should be instructed to hold his breath during the exposure. When this does not exceed 20 or 30 seconds, it is possible with a little practice for the patient to hold his breath. In this way two pictures may be obtained, (1) at the end of inspiration, and (2) at the end of expiration. When the compression is perfect, it is possible to get good radiographs with exposures of one or two minutes.

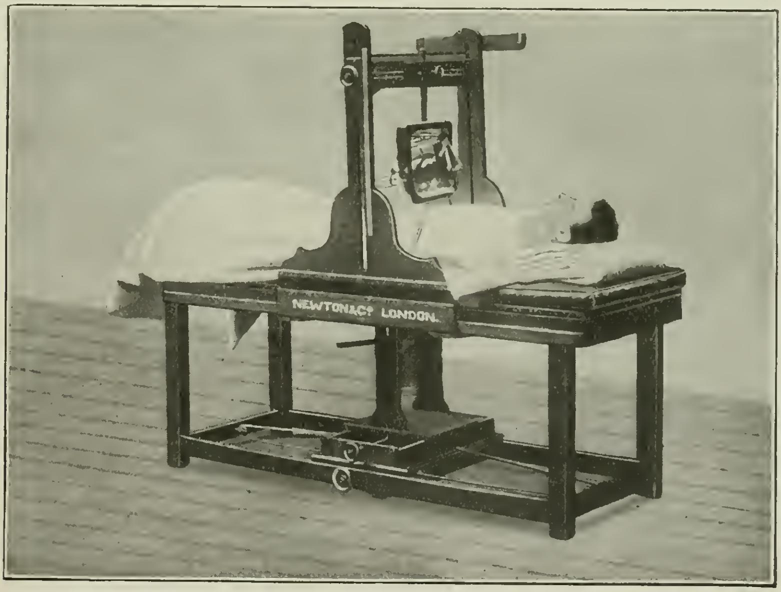


FIG. 314.—X-ray couch to illustrate method of compression.

The next important point in the taking of good radiographs lies in the management of the X-ray tube. Here, again, a great deal depends upon the operator and his knowledge of the apparatus at his command. Good pictures can be obtained with almost any ordinary apparatus. It is not necessary to have elaborate installations in order to get good results. Many of our radiographs have been obtained by the use of a 10-inch coil, a mercury interrupter, and an ordinary X-ray tube. The exposure necessary may vary from an instantaneous flash to five minutes. With a 12-inch coil, a moto-magnetic interrupter, and a heavy anode Müller tube it is possible to get all the necessary detail with an exposure of about ten seconds or less.

The controlling factors are : (1) the amount of current passing through the X-ray tube, (2) the distance of the tube from the plate, and (3) the body weight of the patient. The latter factor is important because the larger the subject the further away from the plate is the tube likely to be.

It cannot be too strongly insisted upon that the controlling factor in all radiographic exposures is the X-ray tube : given a good tube, working at its proper spark-gap and allowing an adequate amount of current to pass through it, one cannot fail to get accurate results. When an imperfect tube is used, no apparatus will give the proper degree of penetration.

When a considerable amount of work has to be got through, it is well to have a number of tubes in working order. If possible, the same type of tube should always be employed, and they should be kept at as nearly as possible the same degree of vacuum. It is possible to keep a tube in good working order by never allowing it to run too long. A good tube will keep in working order for months, if it is carefully looked after. A record of all exposures, time, quantity of current used, and results obtained will be helpful in practice, for then one gets to know exactly what a tube is capable of doing. Prolonged screen examinations are harmful to any tube. Where possible, a special tube should be employed for all such work. In practice, good kidney radiographs have been obtained with all varieties of tubes.

The development of the plate deserves some notice. The radiographer requires to have a special knowledge of this section of his work. Where possible, in all important cases the radiographer should develop the plate himself. In hospital practice this is not possible, but there one generally has a nurse or photographer who looks after the development. In any case it is of importance that the person who develops the plate should have some knowledge of the conditions under which the radiograph has been taken. The developer is usually one containing metol and hydroquinone, though in some cases pyro-soda may be employed. In a properly exposed plate, the development is generally completed in about five to ten minutes.

The plate is fixed in the ordinary way. It should be allowed to fix out in the dark or in a ruby light, though the negative is frequently examined by electric light before it is thoroughly fixed.

We have not seen any harmful results from this premature examination, but nothing is to be gained by a hasty examination, and it is evident that harm may result, so a good rule is never to examine a plate until it has been allowed to fix out thoroughly.

a

b

c

PLATE LXXIII.—Tuberculosis of Kidney and Mesenteric Glands.

a, Calcareous, caseous mass in kidney region, the result of tuberculosis, confirmed at operation.

b, Calcareous patches in left kidney area, probably due to healed tubercle of the kidney ; the larger shadow might easily be a calculus.

c, Calcified mesenteric glands. The appearance of these shadows might lead to a mistaken diagnosis of stones in the kidney.

Anatomical Relations of the Urinary Organs

The kidneys are a pair of bean-shaped organs, each measuring about $4\frac{1}{2}$ inches in length, $2\frac{1}{2}$ inches in breadth, and $1\frac{1}{4}$ inches in thickness, and each weighing about $4\frac{1}{2}$ ounces. They lie in the hypochondriac, epigastric, and umbilical regions, and are placed behind the peritoneum in a kind of lymph space in the fat-bearing subperitoneal tissue, opposite the last dorsal and three upper lumbar vertebræ, the right usually lying about half an inch lower than the left. The long axis of each is directed downwards and outwards. Its antero-external or visceral surface is directed outwards and forwards, its postero-internal or parietal surface looking backwards and inwards. Its outer border representing the angle of junction of its two surfaces is narrow and convex; its inner border, looking obliquely inwards, forwards, and a little downwards, is convex above and below, but slightly concave in its middle third, and fissured by the hilum. The upper extremity is rounded and supports the suprarenal body, which encroaches also upon its anterior surface and internal border. The lower extremity, also rounded, lies further from the median plane than the upper. The hilum is a slit-like aperture in the middle of the inner border of the kidney, bounded in front and behind by two prominent lips. It forms the entrance into a deep depression or cavity, the sinus, at the bottom of which are (1) the renal papillæ, perforated by the openings of the secreting tubules; (2) the apertures transmitting the vessels and nerves to the organ; and (3) the attachments of the "calices" of the main duct, each embracing one or two of the papillæ. The kidney may, in fact, be regarded as a hollow organ.

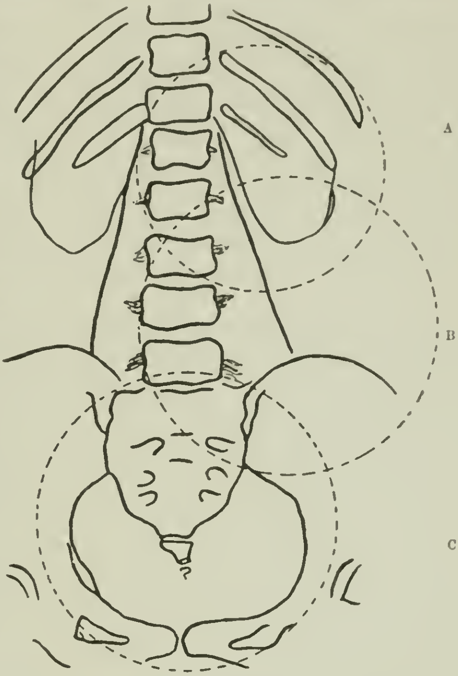


FIG. 315.—Diagram to illustrate the "areas" to be examined in radiography of the urinary tract.

Three exposures are necessary when using the compressor. A, kidney, B, ureter, C, pelvis. Note that each area should overlap the one above it if the whole tract is to be examined. The same procedure has to be followed for the other side. By using a larger extension tube the whole tract may be examined with three exposures, but in that case the tube must be centred over the middle line instead of to either side.

The dotted circles represent the area covered by the extension tube in positions A, B, and C. In region marked A the compressor is tilted upwards, in B the direction is at right angles to the plate, and in C the compressor is tilted downwards towards the feet of the patient.

It is necessary to survey the whole of the urinary tract when examining for suspected calculus. When the compressor tube is used and three "areas" covered care should be taken to ensure that each area overlaps the adjoining one. The last two ribs should be well in the circle. It is then possible to examine thoroughly the suspected side. The normal side should be subjected to the same routine.

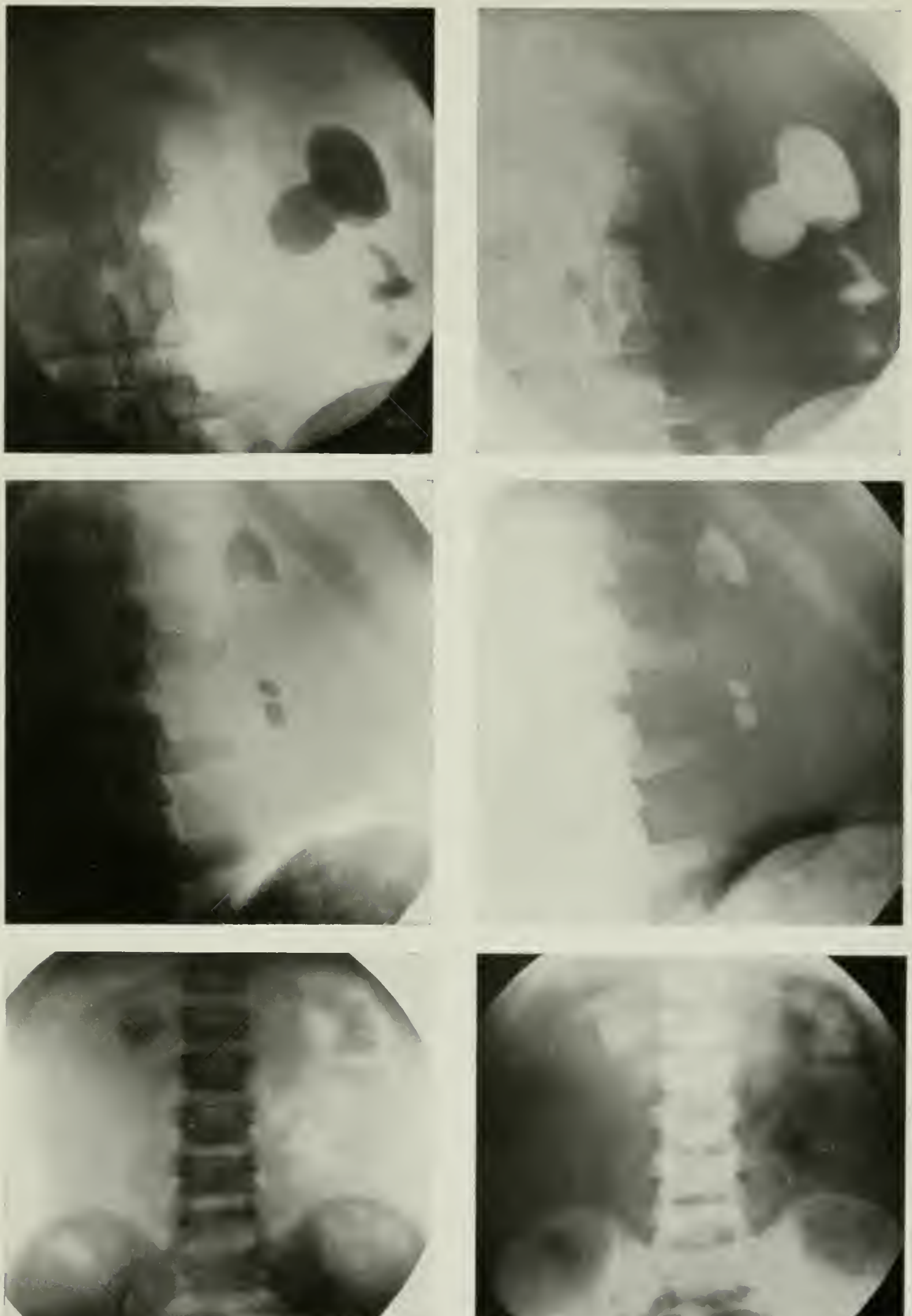
Relations.—In front of the right kidney are the right lobe of the liver, the second stage of the duodenum, the hepatic flexure of the colon, a branch of the colica dextra artery, and more or less of the parietal peritoneum, on the inner side of the latter. In front of the left kidney are the stomach (with the peritoneum of the lesser sac), the splenic artery, the pancreas and the splenic vein, the splenic flexure of the colon, the parietal peritoneum, a branch of the colica sinistra artery, and the spleen (at the outer border). Behind both kidneys are the diaphragm, the psoas and the anterior lamella of the transversalis tendon (covering the quadratus lumborum), with the respective fasciæ of those muscles and the last dorsal, the ilio-hypogastric and the ilio-inguinal nerves. The diaphragmatic area is generally larger on the right side, and may be considerably increased on either, when the external arcuate ligament passes to the second lumbar process instead of the first.

The ureters are about a foot long, and lie in a sheath of subperitoneal tissue over the psoas muscles, passing behind the spermatic vessels, and after crossing the common or external iliac artery, disappear into the pelvis, where they can be traced to the bladder. The right ureter runs behind the second stage of the duodenum, and lies close to the inferior vena cava. In the female, both ureters approach the sides of the cervix uteri, and lie in contact with the upper part of the vagina, crossing it obliquely to reach the base of the bladder. The proximal extremity of each ureter begins with eight or nine short tubes called calices, which surround the renal papillæ at the bottom of the sinus. These join each other, with or without the intervention of short passages called infundibula, to form usually two tubes, the upper and lower pelvis, and the union of the two pelves constitutes the common renal pelvis, which generally narrows to the size of a goose quill, and becomes the ureter proper. The ureters pierce the bladder at the junction of the posterior or lateral walls, about an inch and a half above the base of the prostate. The left ureter is contained in the root of the posterior false ligament of the bladder (or in part of the broad ligament in the female), and can be traced beneath the peritoneum to its entrance into the fundus of the bladder.

Diseases of Urinary Tract

In order to make a diagnosis from negatives of the urinary tract in disease, it is necessary for the radiographer to be familiar with the appearance of good normal negatives from the region of the kidneys, ureters, and bladder. This knowledge can be acquired only by regular practice, though it is possible to demonstrate the essential points by means of a series of radiographs. A good radiograph of the kidney area should show the outline of the organ, and should cover the whole of the kidney. In order to get the whole of the area, it is necessary to get the two lower ribs in the picture.

Bearing in mind the normal appearances of the urinary tract, we now proceed to a consideration of the abnormalities which may be met with in the investigation of diseases of the urinary organs. Before considering those



a

b

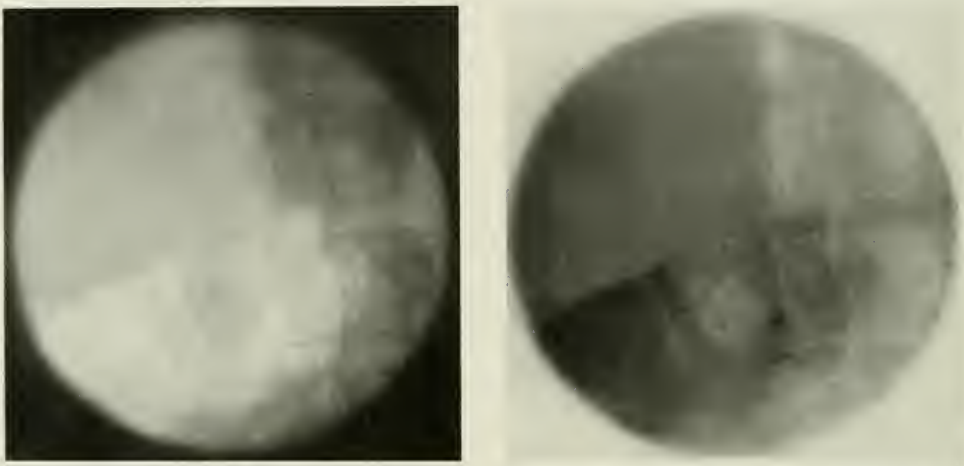
c

PLATE LXXIV.—URINARY CALCULI.

a, Calculi in kidney.
b. Calculi in kidney. (Radiograph by C. Thurstan Holland.)
c, Fæcal mass in kidney area simulating calculus.

a

b



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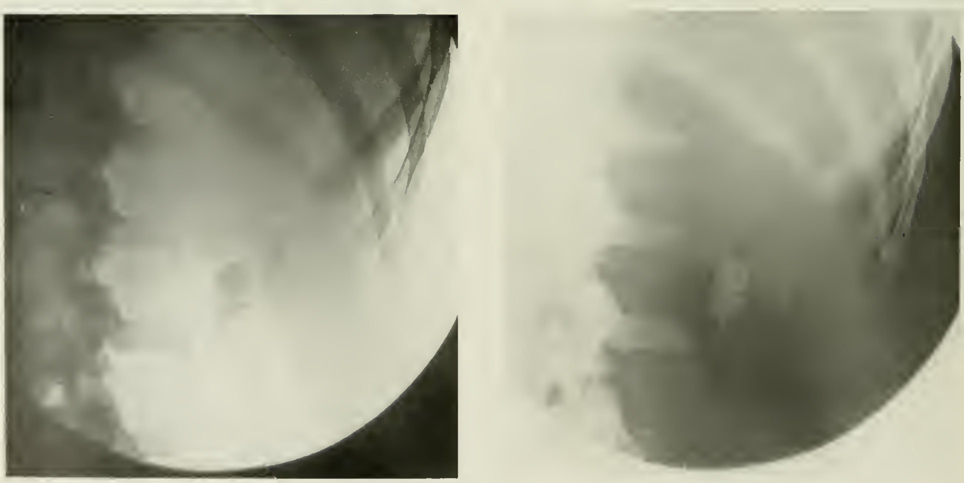


PLATE LXXV.—URINARY CALCULI AND GALLSTONES.

a, Small calculus in bladder. Phlebolliths on right and left sides of pelvis.
b, Gallstones in gall bladder. Plate on anterior aspect of abdomen.
c, Two gallstones ; note position below the kidney shadow. (Radiograph by C. Thurstan Holland.)

diseases in order, it is necessary to consider some of the conditions which, when met with, are apt to mislead the observer and cause errors of diagnosis. Those are numerous and ever increasing in number as fresh cases are recorded.

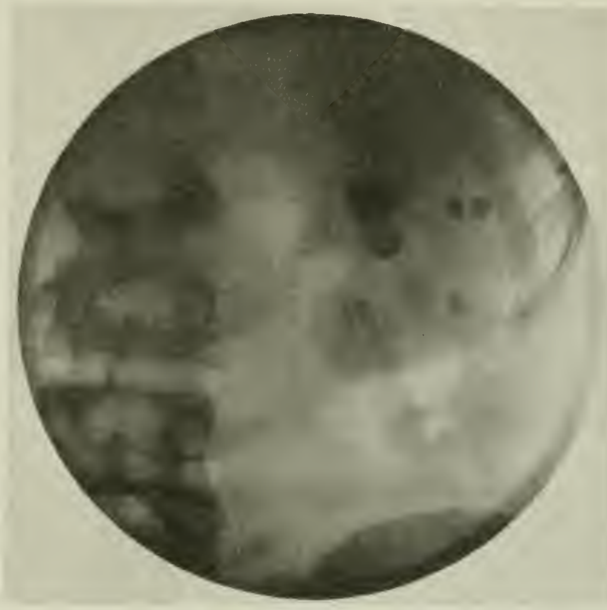


Fig. 316.—Multiple shadows in the right kidney region.

(1) Fæcal matter in the intestines. This is a common cause of mistake in diagnosis, but if the necessary preparatory measures recommended are carefully carried out this cause should never occur.

Plate LXXIV., Fig. *c*, illustrates an instance of this kind, where a large shadow is seen in the pelvis of the kidney, which might easily have been diagnosed as a large stone. A second radiograph, taken two days later after free purgation, shows the mass lower down in the colon. The point which led to a diagnosis of fæcal matter was the loaded condition of the colon over the opposite kidney region.

Fig. 317.—Kidney area, showing stone in right kidney. (*a*) Inner edge of kidney; (*b*) stone; (*c*) edge of psoas muscle. The tube has been centred over the middle line. Both kidney areas are in the picture.

(2) Foreign bodies in the intestine may be mistaken for calculus.

(3) Enlarged and calcified mesenteric glands are another element leading to error in urinary diagnosis.

(4) The case of

foreign bodies in the kidneys, introduced at the time of a previous operation, must not be overlooked.

(5) Concretions in the appendix have been mistaken for ureteral calculi.

(6) Phleboliths are another common cause of mistaken diagnosis. These are found low down in the pelvis, and may be mistaken for stones in the ureter.

Phleboliths are not generally found in young patients, though it is difficult to fix an age beyond which they are found. The commonly assigned cause is that inflammation in the vein wall leads to deposits of fibrous and calcareous matter, which show when the patient is radiographed. The position is often helpful in differential diagnosis. They are generally found away from the line of the ureter, occupying the line of a vein or veins. Commonly found opposite the ilio-pectineal eminence. The shape of the shadow is often a guide to its nature, phleboliths being generally rounded shadows showing variations in density, while small stones in the ureter are generally oval or elongated. The direction of a shadow is also a guide. Even when all these points are kept in mind cases will occur where it is impossible to differentiate (see Fig. 318).

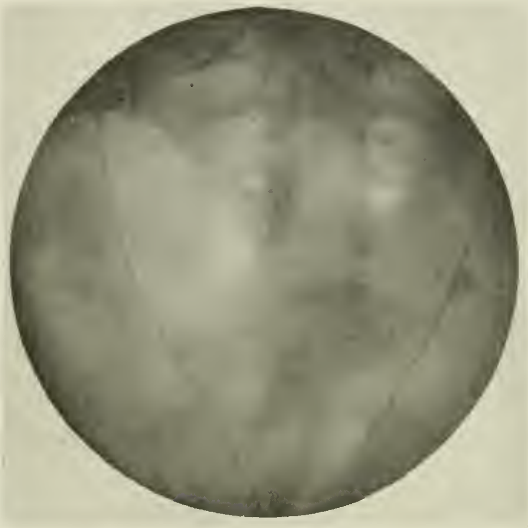


FIG. 318.—Pelvis showing opaque catheters in ureters.
On the right a shadow is seen at the outer side of the catheter. Examined stereoscopically the shadow was seen to lie behind the ureter, and this was confirmed at operation.

Urinary Calculi.—1. In the Kidney.—Stones may be found in any part of the kidney. The most frequent position is in the pelvis or calices. They vary in size and composition. The commoner stones are the oxalates and the uric-acid and phosphatic varieties, the uric-acid calculi being the most frequently met with. A rarer variety is composed of cystin. The great majority of kidney stones, however, are of mixed composition. It is very rare to get a pure uric-acid calculus. The shadows thrown by stones vary in density, the oxalic variety giving the densest shadow, the phosphatic next, and lastly the uric-acid variety. Stones may vary in shape. Large stones have been found to occlude the pelvis, and to have branched ramifications, filling up the calices. Small calculi may be found in the substance of the kidney, and vary in size from minute bodies to the size of a hazel nut. When many calculi are present they are usually faceted.

Fig. 316 is an interesting example of multiple shadows in the renal area.

Urinary Calculi.—2. In the Ureter.—A small stone will find its way down the ureter into the bladder. The passage of a stone is usually accompanied by symptoms, the chief of which is renal colic. This may be severe in character, and does not bear an exact relationship to the size of the stone. A small irregular stone may give rise to very severe renal colic ; a larger smooth stone may pass more readily down the ureter, and not give rise to marked symptoms. The stone in its passage down the ureter may be arrested at any part of its course, the commonest seat of arrest being in the pelvis, close to the entrance to the bladder. The symptoms may be marked

Fig. 319.—Stone in ureter.

(By kind permission of Mr. Collinson. Radiograph by Dr. Rowden.) The calculi shown in the radiograph are remarkable. The notes of the case are here given.

Patient aged 27 years. At age of 4 an attack of acute pain in the left renal region followed by hæmaturia. Many similar attacks followed, but were not always accompanied by hæmaturia. At age of 12 a skiagram was taken and calculus in the left kidney was diagnosed but no operation advised. Between that time and the date I saw her attacks of pain had recurred with considerable frequency, and after leaving school she followed no occupation till the age of 22, when she became a barmaid. Had often to return home on account of pain. During 1910 several severe attacks of hæmaturia.

On Examination.—Left kidney not palpable ; in the region of the left ureter a long, hard, sausage-shaped tumour can be felt extending from the lower pole of the kidney to the pelvic brim ; per rectum a similar mass can be felt in the region of the termination of the left ureter. Its lower extremity is pointed and can be moved slightly from side to side.

Skiagram showed no shadow in left kidney ; in region of left ureter a continuous shadow extending from the pelvis of the kidney to the brim of the true pelvis, and below this a second shadow extending to the entrance of the ureter into the vesical wall. The calculi appear to be articulated with one another at the pelvic brim.

Cystoscopic Examination.—Twenty minutes after injection of indigo carmine. Right ureteral orifice normal and excreting jets of blue urine vigorously. Left orifice situated on a mound-like elevation. No blue urine issuing, but an occasional feeble jet of blood-stained fluid. Ureteral catheter enters orifice easily, but is arrested at a point $\frac{1}{2}$ inch from the opening.

Operation, 17*th March* 1911.—Kidney exposed and found to be hydronephrotic. No calculi in kidney. Ureter much dilated and containing a calculous cast which extended from renal pelvis to below the brim of true pelvis. Below this a second calculus articulating with the first and reaching as far as lower end of ureter. The lower calculus was removed with some difficulty owing to the upper end hitching below the pelvic brim. Ureter considerably torn owing to its friability, nephrectomy, and ureterectomy. Recovery uneventful.

A section of the lower calculus shows that its apex is formed by a small renal calculus, and that the remainder of the calculus has been formed by the deposit of successive layers of phosphates.

according to the degree of occlusion caused by the stone. A stone which completely blocks the ureter leads to an accumulation of urine in the portion of ureter above the seat of occlusion and in the kidney. When the occlusion is not complete, the passage of urine is not completely arrested, and the more distressing symptoms may be absent. It is interesting to note that a stone may remain in the ureter for many months, and only occasionally give rise to symptoms of pain, hæmaturia, etc. An examination of the urine for pus and epithelial cells may help to determine the presence of a stone in the ureter. In several cases we have watched the passage of a small calculus down the ureter, and in one instance repeated examinations showed that the stone was slowly travelling down to the bladder ; the symptoms were not severe, attacks of colic at intervals of months indicating the progress of the stone. Ultimately it was passed into the bladder and voided in the urine. This is by no means an uncommon occurrence, and should be kept well in mind when we have to consider the question of operative interference in a case where the presence of a stone has been demonstrated in the course of the ureter. If the symptoms are not acute, all small ureteric calculi should be given every facility to pass into the bladder before a serious operation is contemplated.

FIG. 320.—Large stone in the bladder.
The variations in the density of the stone are well shown.

An important point in connection with ureteral stones is that when one has been demonstrated in the line of the ureter it is necessary to make another examination prior to operation; and it should be noted that when any doubt exists an opaque bougie should be passed into the ureter to determine that the stone is actually inside the lumen. Mistakes in diagnosis will then be minimised, and the patient occasionally spared a needless operation.

What might be termed a migratory stone in the ureter is well illustrated by a case occurring in the practice of Dr. Thurstan Holland of Liverpool, where a large stone was found to occupy a position in the lower ureter and pelvis of the kidney alternately. At the operation it was found that the ureter was dilated to an enormous extent.

Urinary Calculi.—3. In the Bladder.—A vesical calculus may be formed of almost any of the urinary deposits met with, and each has its own characteristics.

(*a*) The uric-acid calculus is usually oval in shape and flattened, and of variable density. On section it is distinctly laminated with a smooth or slightly undulating surface of a brownish colour. It may be crusted with phosphatic material. A pure uric-acid calculus gives a faint shadow radiographically.

(*b*) The urate of ammonium calculus is of a similar structure, but of lighter colour.

(*c*) Oxalate of lime calculus is a rough irregular body, not infrequently tuberculated or even spiculated. It is extremely hard and dense, of a reddish-brown colour, or sometimes black, owing to admixture with blood. It is rarely of great size, on account of the irritation caused by its presence and its slowness of growth.

(*d*) A pure phosphatic calculus is somewhat rare, but any stone or foreign body is certain to become coated with a phosphatic deposit when chronic cystitis has resulted in alkaline decomposition of the urine.

(*e*) Cystin forms the base of a rare calculus.

(*f*) Xanthine or xanthic oxide is occasionally met with, but is very rare. The presence of a calculus in the bladder is readily shown by X-ray examination. Such an examination is most helpful to the surgeon, for it demonstrates the presence of stone or stones, the number of the calculi present, and to some extent the position.

In all cases of urinary calculi several examinations should be made, unless very definite evidence is obtained on the first occasion. No opinion negative or positive should be given without at least one confirmatory examination, and where an operation is contemplated a final radiograph should be taken immediately prior to the operation. In important cases this should be done even while the patient is under the anæsthetic, and the plate developed ; the surgeon will then have a very definite guide for reference during the actual operation.

Tuberculous Disease of the Kidney is of comparatively frequent occurrence, and is one of the first conditions to be suspected when radiographic examination has failed to show the presence of a stone. It may occur in one of three forms : (*a*) *Acute general tuberculosis*, when miliary tubercles are found studding the organs. Radiography is rarely of much service in this variety. (*b*) *Ascending tuberculosis* may arise from a similar affection of the bladder. The mucous membrane of the ureter becomes thickened and the pelvis and calices also become affected. On clinical examination enlargement of the kidney is the next manifestation. Radiography may be helpful in demonstrating the enlarged kidneys ; and when caseous matter is present or abscesses form, the negative may show these affections. (*c*) *Primary tuberculosis* of the kidney is generally unilateral, and commences as a deposit of tubercle in the cortex or at the base of one of the pyramids ; a caseous mass forms, which may extend widely, causing disintegration of the kidney substance. Variations in density in the kidney shadow may be an indication of the presence of this condition.

Enlarged Movable Kidney.—This may be (*a*) simple, or (*b*) complicated by calculi. The kidney may be found to be freely movable, and may be palpable. Screen examination will reveal its position and the amount of mobility. A stone, if present, is readily demonstrable. The following illustrates a case of this kind : A lady about thirty-five years of age complained of a constant pain in the right side. Examination revealed a freely movable kidney on the right side, the lower pole being very tender and hard. Radiographic examination showed the enlarged organ displaced downwards. Two definite shadows in the cortex indicated the presence of two small stones.

A large irregular shadow in the lower pole led to some discussion as to its nature. It was evidently in the kidney or attached to it, because it moved with the kidney. A diagnosis of stones in the kidney was made. At the operation two small calculi were removed. The appendix was found to be distended, and in all probability this may have accounted for the larger shadow. The patient was examined about five years later, when shadows, two definite and one indefinite, were seen in the lower pole of the kidney. These were due to calculi which were surgically removed. Thickened capsule of the kidney may give shadows suggestive of stone, especially when the pelvis is thickened.

Tumours of the Kidney.—These are numerous and worthy of notice, the tumour being either simple or malignant. The general characteristics are as follows : A swelling is noticed in the loin, shaped more or less like the kidney, a notch being occasionally felt on the inner border, and the outer margin being rounded. The flank is dull on percussion, the passage of the colon in front of the kidney occasionally giving a note of resonance over its anterior surface. The mass moves slightly on respiration.

Simple Tumours.—Cystic disease, which may be congenital or acquired, is the usual form of simple tumour. It is not infrequently bilateral when congenital. Especially when congenital, the kidney is enlarged and occupied by cysts of various size, but rarely exceeding that of a cherry. They are lined with epithelium, which is generally flattened, and filled with a limpid fluid containing urea and perhaps cholesterine. The pelvis remains unaffected until the later stages of the disease. Generally the whole kidney is affected, and may attain enormous dimensions. But occasionally the growth is limited to one part of the organ. The early symptoms are simply those of pressure, but at a later stage the secretion of urine is interfered with to such an extent as to produce uræmia. The radiographic examination of this condition is unsatisfactory. In the majority of cases the enlargement of the organ may be shown, and occasionally variations in the density of the kidney shadow may lead one to suggest the presence of fluid in the organ. One generally excludes the presence of stone in such cases, and when the symptoms are not such as to suggest acute hydronephrosis or tuberculosis then the presence of fluid showing in the radiograph may enable one to give a diagnosis of cystic kidney. We have examined a number of cases of enlarged kidney with no active symptoms, and in several a diagnosis of cystic disease of the kidney has been arrived at, and confirmed on operation. One case under observation at the present time in an adult shows shadows of considerable size in both loins. The patient has had active hæmaturia, presumably the result of traumatism.

Malignant Disease of the kidney may be divided into :

(1) The sarcomata of infants, which are often congenital, but may be acquired within the first few years of life. They grow to a great size, and may affect both organs. Pain and hæmaturia are absent.

(2) The sarcomata of adults occur most commonly between the thirtieth and fiftieth years of life, and are of the spindle-celled variety.

(3) Carcinoma of the kidney is an uncommon form of tumour. It is frequently associated with the presence of a varicocele, the results of pressure from carcinomatous glands.

(4) Hypernephroma arising from suprarenal tissue is not uncommon.

Various Cystic Conditions of the kidney may be noted in addition to the general cystic disease already mentioned :

(*a*) Hydatid disease affects the kidney, as any other organ of the body.

(*b*) Dermoid cysts have also been found.

(*c*) Serous cysts are occasionally met with.

One point is worthy of note in connection with the systematic examination of the kidneys. The attention directed to the suspected kidney should not lead the observer to ignore the other and presumably sound organ. When it is definitely settled that one organ is diseased and an operation is decided upon, the radiographer should proceed to demonstrate the presence of the other organ and should satisfy himself that its condition is normal. It occasionally happens that a patient comes up for examination who has been operated upon before. The presence of a scar in the loin suggests an operation, but the majority of patients have no actual knowledge of what has been done. The radiographer has then to demonstrate the presence or absence of the kidney on the side which has been operated upon. If he finds the kidney has been removed, then he proceeds to examine the other kidney. Should the patient have symptoms of disease on this side, the knowledge that one kidney has been already removed will be of great service to the surgeon.

Occlusion of the Ureter.—The ureter may be occluded as a result of cicatricial changes in its walls following laceration from the passage of a calculus. A simple stricture of the ureter may result. A calculus may completely block the ureter, and lead to acute symptoms of obstruction.

Fig. 321.—Calculus in ureter.
Opaque bougie passing up to the calculus. This was confirmed at operation.

The ureter may be obstructed by pressure in any part of its course ; tumours of neighbouring organs occasionally lead to an obstruction. Tumours in the pelvis may gradually occlude both ureters and lead to suppression of urine. All these conditions may be met with in the examination of the urinary tract, and should be well borne in mind. A negative diagnosis of stone may be made, and in some cases the cause of the obstruction may be determined by a careful examination.

Fig. 322.—Calculi in ureter.

In doubtful cases of kidney disease there are other methods of examination which may be regarded as supplementary to the methods described. The examination may be rendered more valuable and absolutely diagnostic in suspected stone in the ureters, or when shadows are shown in the line of the ureters, by the passage of opaque bougies into the bladder and ureter. A radiograph taken should show the bougie in the canal, and the relationship of the shadows to it.

In an examination of this kind, made to determine the relationship of a doubtful shadow in the line of the ureter, it is important to remember that when the catheter passes the stone it does not follow that the stone is outside the ureter. The catheter may have slipped past the stone in a case where the ureter is dilated. Similarly the catheter may lie in front of or behind the stone, and stop at the upper limit of the stone shadow. An opinion may then be given that the stone is not in the ureter. This may be an erroneous conclusion. Stereoscopic plates will show the correct relationship of the stone to the shadow of the catheter. When several shadows are in the ureteral line and the catheter passes between them with a clear interval on either side of its shadow, it may safely be assumed that the shadows are not those of stones in the ureter.

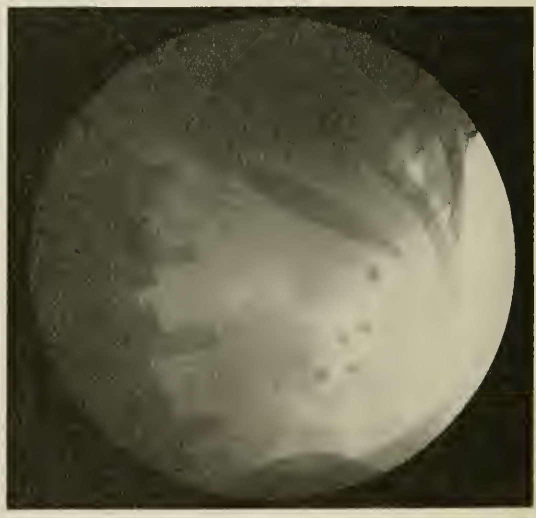


Fig. 322*a*.—Calculi in kidney.

Figures 322 and 322*a* illustrate several stones in the ureter and kidney on the left side, where the stones at several examinations were seen to have

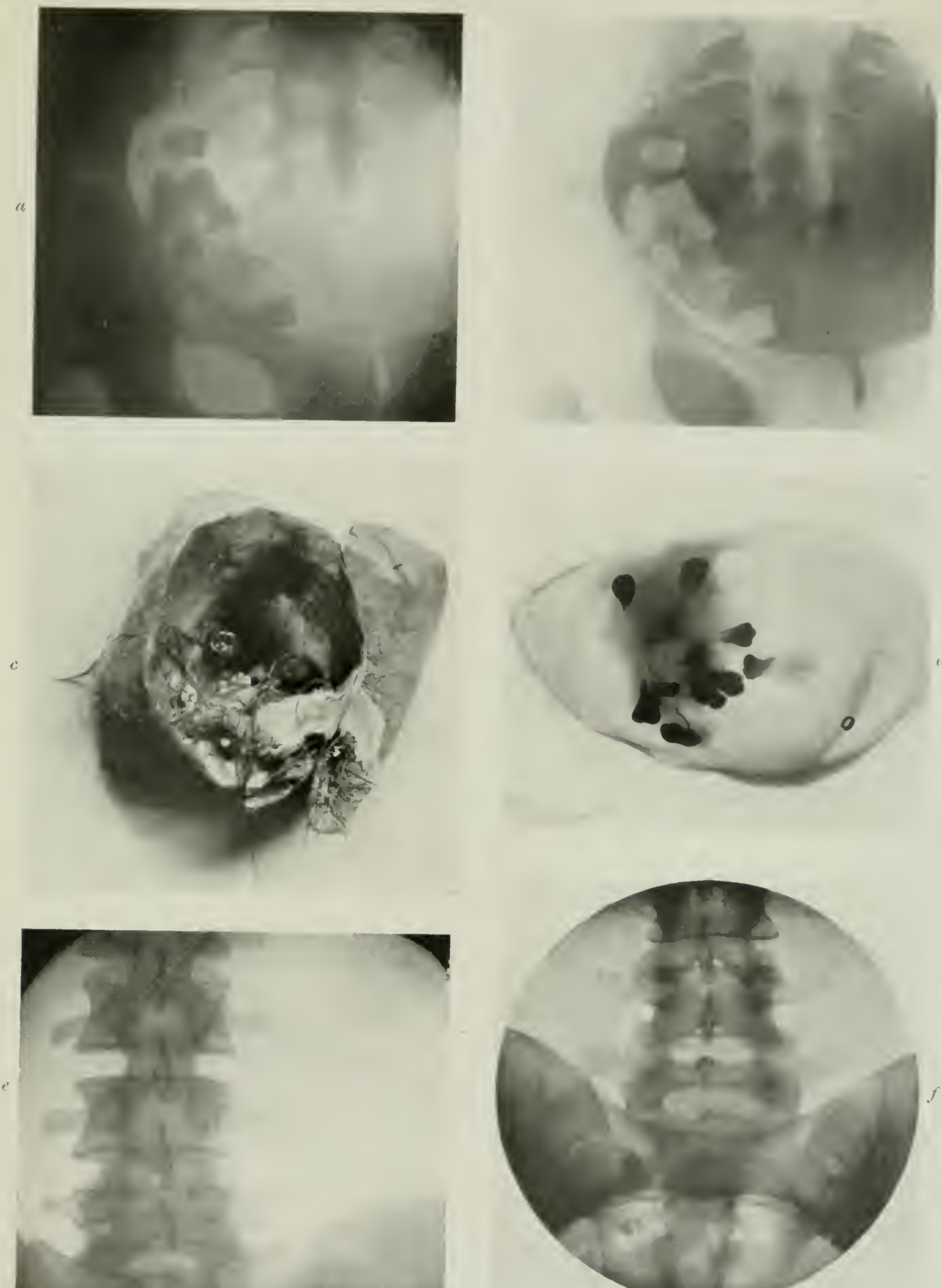
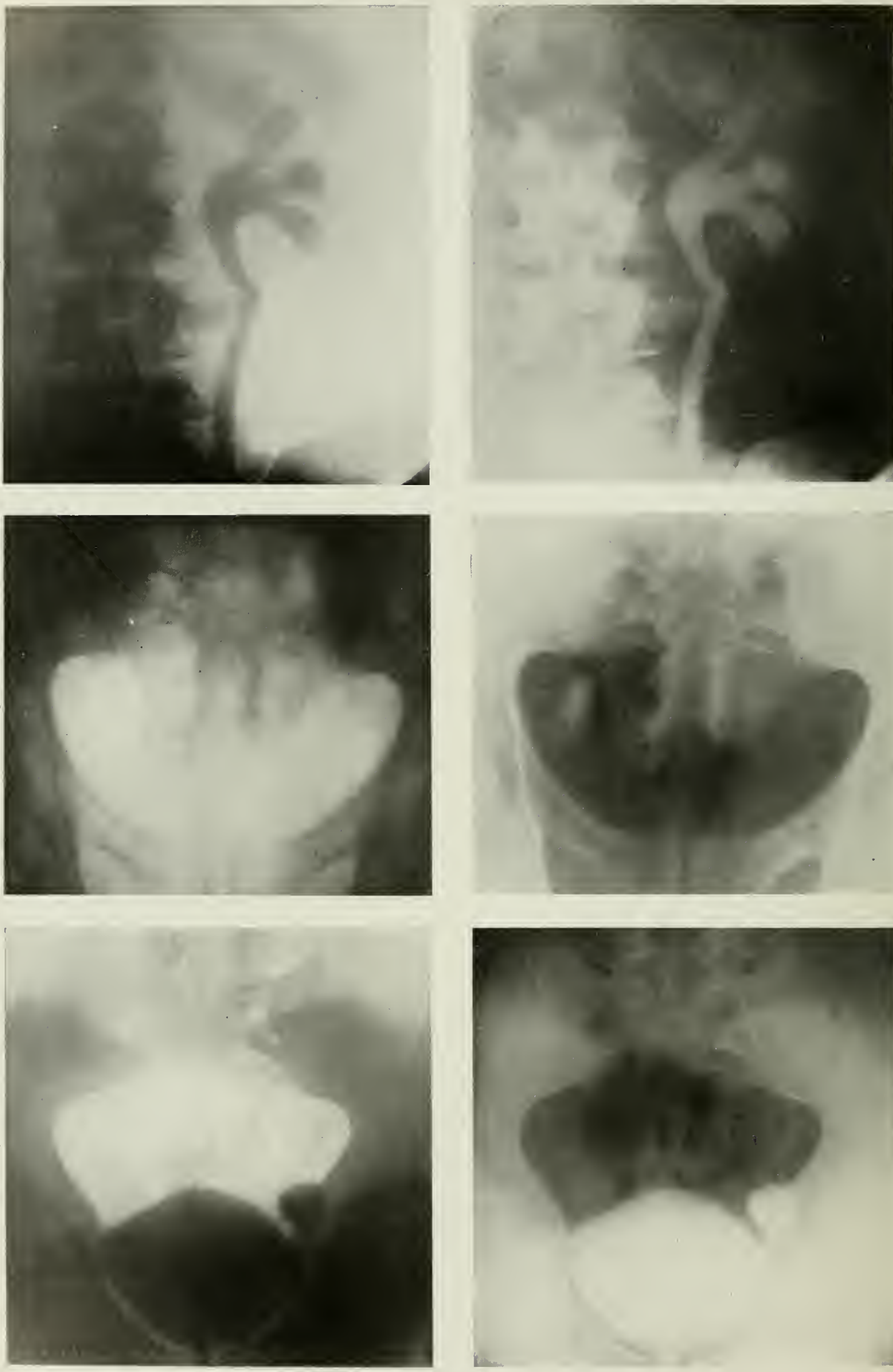


PLATE LXXVI.—DERMOID CYST IN PELVIS. MULTIPLE SHADOWS IN RENAL AREA, AND PELVIS SHOWING CALCAREOUS GLANDS.

Dermoid cyst in pelvis. *a* and *b*, Radiograph of pelvis showing cyst.
c, Photograph of cyst after removal.
d, Radiograph of cyst after removal by operation. Note the teeth in the cyst.
e, Multiple small shadows in right renal area.
f, Pelvis showing calcareous glands on right side.



a

b

c

PLATE LXXVII.—Kidneys, Ureter, and Bladder.

a, Collargol in pelvis of kidney and ureter. (Radiograph by C. Thurstan Holland.)
b, Calculus in ureter.
c, Barium injection of bladder to show diverticulum, opaque bougie in ureter.

Mr. Everidge's case.

changed their positions relative to the kidney and the ureter. The ureter in this case was greatly dilated.

An interesting case of doubtful shadow in the line of the ureter is recorded by Thurstan Holland, where the only indication against the shadow being that of a ureteral stone was its unusual direction in relation to the ureteral line. It was found at operation to be due to a tooth in a dermoid cyst.

A second method in doubtful cases is to inject into the ureter and pelvis of the kidney a solution of collargol, it being possible to demonstrate dilatation of the ureter and calices of the kidney by this method. The existence of hydronephrosis of the kidney is rendered visible when the kidney has been injected, while kinks and contractions of the ureter may also be shown by this method.

Technique of the Examination of the Urinary System with Collargol Solution

Position of the Patient.—The recumbent position is the best, the patient lying on a hard couch; anæsthetics are not employed as a rule.

Demonstration of the Ureter.—There are several ways in which the ureter can be demonstrated:

(1) By the use of a silver stylet enclosed in an ordinary ureteral catheter.

(2) By the use of catheters or bougies impregnated with bismuth.

(3) By the use of specially prepared ureteral bougies.

(4) By the use of collargol solution.

Nos. (3) and (4) are those usually employed, and of these two the collargol method is the more certain. An ordinary catheter *in situ* is filled with collargol, and radiographed, or the radiogram is taken while the collargol is trickling down the ureter from the pelvis of the kidney.

Strength of the Solution employed.—Solutions of from 3 to 20 per cent are employed, but 10 per cent is the most usual strength. The strength employed should be selected according to (1) the stoutness of the patient; (2) the degree of hydronephrosis, if this be present. A weak solution should be employed if an abnormal shadow has been detected in the renal pelvis, for should there be a stone in the pelvis or in a calix, and too strong a solution be used, it is probable that the collargol shadow may obliterate that of the calculus.

Dangers arising from the Use of Collargol.—(1) Cases of sepsis have been reported; (2) areas of necrosis, infarct, and cast formation have been known after the distension of the pelvis under high pressure. Strassmann has carefully investigated these points, and has come to the conclusion that the injection of collargol in proper quantity and under moderate and careful pressure causes no harmful results.

Thorium is advocated by Dr. J. Burns[1] as a substitute for collargol.

[1] "Thorium," by J. Burns, M.D., *Bulletin of the Johns Hopkins Hospital*, June 1916.

It is non-toxic, non-irritating, and is readily eliminated; it is also inexpensive. A safe solution for clinical use is given as follows:

To make 100 c.c. of a 10 per cent solution, 10 grms. of thorium nitrate are dissolved in as little distilled water as possible. To this solution—kept on a water or steam bath—are added 30 c.c. of a 50 per cent solution of sodium citrate; make the additions in small quantities, and shake thoroughly after each addition.

(At first, after the addition of the citrate solution, a white gummy precipitate is formed, which later becomes granular, and finally dissolves on the addition of all the citrate solution.)

The solution is then made neutral to litmus by the careful addition of a normal solution of sodium hydroxite, and made up to the required volume of 100 c.c. with distilled water. On filtration a clear limpid solution is obtained, which, when sterilised either by boiling or steam pressure, is ready for use.

This solution contains approximately 15 per cent of thorium nitrate, about 9 per cent of sodium nitrate, and 21 per cent of sodium citrate, the thorium being most probably in the form of a double citrate of sodium and thorium. The thorium content alone casts the shadow.

The gravity method should be used for its introduction into the kidneys and ureters.

Sacculi of the Bladder.—These may be shown radiographically, but solutions of barium sulphate are used instead of collargol on account of the cost. Two parts of barium sulphate are suspended in ten parts of oleum amygdalæ dulcis, and this suspension corresponds well with collargol solution in density of shadow produced.

a

b

c

d

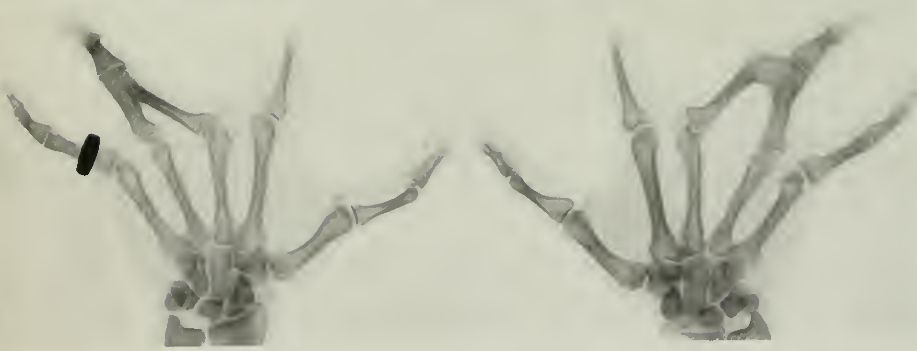


PLATE LXXVIII.—CONGENITAL DEFORMITIES.

a, Meningocele in an infant.
b, Congenital deformity of foot (Talipes valgus).
c, Photograph of congenital deformities of hands.
d, Radiograph of above.

CONGENITAL MALFORMATIONS

All varieties are met with in the routine examination by X-rays. Valuable information may be obtained as to the presence of these abnormalities, their form and extent, and light is thrown upon them from the operative point of view.

It is impossible to give a complete account of the departures from the normal which occur in all parts of the body, but a few of the commoner instances may be mentioned ; several are illustrated in Plate LXXVIII. The skull frequently presents departures from the normal, in ossification, and absence of sinuses, notably the frontal, where there may be practically no air-cells, or a very small one may represent the frontal sinuses. The sinuses may be abnormally large, and extend over the greater part of the frontal bone ; one side may be quite normal or greatly enlarged, while the other is absent. Similarly the mastoid air sinuses may vary to a like degree. Abnormalities in the eruption of the teeth are often seen. In the thorax the viscera may be transposed, the heart being on the right instead of the left side, the aorta being similarly displaced. The stomach is occasionally found on the right side, the liver being then on the left. The cæcum and appendix may also be found on the opposite side. The kidneys may be represented by a single horseshoe-like structure, or a kidney is found on the one side, the other being absent. It is important in connection with kidney operations to bear this fact in mind.

Many deformities of the bony skeleton are met with. One arm may be represented by a small atrophied structure which may have the bones complete or may show remarkable variations from the normal. The forearm may show a variety of departures from the normal. Congenital absence of a bone is not uncommon. The wrist and hand may be represented by a small fleshy mass with a number of partially ossified bones in its interior, or the fingers may be webbed or joined by bone to each other. The value of a radiographic examination in these cases is great, for by its means it is often possible to determine if the condition can be remedied by operative measures.

GLOSSARY

Accumulator. A secondary or storage battery.

Actinic Ray. A ray of light or other form of radiant energy capable of producing chemical action.

"Alive." A wire is said to be alive when an electric current is passing along it.

Alternating Current. Currents whose directions are periodically reversed.

Ammeter or **Amperemeter.** Any form of galvanometer which is capable of measuring current strength in amperes.

Ampere. Unit of strength of the electric current, exerted by an electromotive force of one volt through a resistance of one ohm.

Anode. The positive pole of an electric battery or the electrode connected with it.

Anti-cathode of X-Ray Tube. A plate of platinum or other metal, supported inside an X-ray tube upon which the cathodic stream impinges.

Aperiodic Galvanometer. A galvanometer whose needle comes to rest without oscillations.

Armature. A coil of wire made to cut the lines of force from the field magnets.

Automatic Cut-Out or **Switch.** A device for automatically cutting off the current at any predetermined period of time by means of a time relay.

Battery. Apparatus for the production of an electromotive force.

Blowing a Fuse. The melting of a wire by the passage of an electric current through it.

Break (noun). (*a*) An instrument for periodically interrupting a circuit; (*b*) any interruption in an electric wire.

Break (to—verb). To interrupt an electric circuit as opposed to closing the circuit.

B.T.U. Board of Trade unit = 1000 watt-hours.

Buckling. The disintegration of the surface of the plates of a storage battery.

Calibrate. To determine the absolute values of scale divisions of an electrical instrument such as a galvanometer, voltmeter, wattmeter, etc.

Candle-Power. The intensity of light emitted by a luminous body estimated in standard candles.

Capacity of Condenser. The quantity of electricity a condenser is capable of holding in coulombs when charged to a pressure of one volt.

Cathode. The negative pole of an electric battery, or the electrode connected with it.

Cathode Rays. Rays originating in a vacuum tube at the negative terminal, when a discharge of electricity is passed through the tube. They are not identical with the Röntgen rays, since they are deviable by a magnet and by refracting media, and are rapidly absorbed by opaque bodies and by the atmosphere.

Circuit. A term employed to denote the total electrical path of an installation.

Commutator, Current Reverser. An apparatus for reversing the direction of the current.

Condenser. An apparatus for storing a large amount of electricity.

Conductor. Any substance which conducts or possesses the power of conducting electricity.

Continuous Current (also called Direct). A current whose direction is constant, as distinguished from alternating current.

Coulomb. Is that amount of electricity which is carried by an ampere flowing for one second past any given point in the circuit. There are 3600 coulombs in one ampere-hour.

Current Strength. In a direct-current circuit the quotient of the total electromotive force divided by the total resistance, or $C = \frac{E}{R}$.

Current Transformer. (*a*) An instrument for changing an alternating into a direct current, or *vice versa* ; (*b*) a device for altering the pressure of a current, which may be either a step-up, *i.e.* raises the pressure, or a step-down transformer, *i.e.* lowers the pressure.

Dead-Beat Galvanometer. A galvanometer whose needle comes quickly to rest instead of repeatedly swinging to and fro, through being heavily damped.

Dielectric. Any material which offers high resistance to the passage of an electric current.

Difference of Potential. When electricity moves, or tends to move, from one point to another, there is said to be a difference of potential between them.

Discharge. The disruptive passage of electric current when opposite polarities approximate, or a sudden equalisation of potentials.

Dynamo. A machine for the conversion of mechanical energy into electrical currents by means of electro-magnetic induction.

Dyne. The unit of force, *i.e.* the force which, if it acted for 1 second on a mass of 1 gramme, would, if the mass were previously at rest, give it a velocity of 1 centimetre per second.

Electric Efficiency. The ratio between the amount of current generated and the expenditure required to produce it.

Electroscope. An apparatus for detecting the presence of an electric charge or determining its polarity.

E.M.F. Electromotive force. The force exerted by an electrical charge.

Erg (*ergon*, work). The unit of work. It is that which is effected in raising 1·981 gm. to the height of 1 centimetre.

Farad. The practical unit of electric capacity.

Fault. Any defect in the proper working of a circuit.

Field (Magnetic). The space about a magnet through which its influence is active.

Filtration of X-Rays. Placing in the path of the rays some medium such as aluminium or felt, in order to absorb some of the softer radiation.

Fluorescent (fluoroscopic) **Screen.** A screen covered with fluorescent material, which permits the visual examination of the human body by means of X-rays.

Fuse (Safety). A soft metal wire interposed in a circuit, which will melt if a current too strong for safety passes through it.

Gap-Spark. The space between the terminals of two conductors.

Hard. Hard and soft are terms applied to X-ray and other vacuum tubes ; they refer to the relative completeness of the exhaustion therein of the retained air or residual gas. A hard tube has a higher resistance than a low or soft tube.

Henry. An electrical unit of inductance equal to the inductance of a circuit when the electromotive force induced in it equals 1 volt when the exciting circuit varies at the rate of 1 ampere per second.

Hot-Wire Meter. A meter whose readings are based on the expansion of a wire, due to an increase of temperature, by the passage through it of the current that is to be measured.

Hysteresis. A term applied to residual effects in the rapid magnetisation and demagnetisation of a soft iron core lying within a coil of insulated wire, through which an interrupted constant current is flowing.

Induced Current. That secondary current produced by induction. It flows in the opposite direction to the primary or inducing current when the latter is made, but in the same direction when it is broken.

Induction Coil. An apparatus consisting of two associated coils of insulated wire employed for the production of currents by mutual induction.

Insulator. A non-conductor or a bad conductor, *e.g.* glass, rubber, shellac.

Intensifying Screen. A surface coated with some fluorescing material, such as tungstate of calcium, placed in contact with the film side of the X-ray plate ; the time necessary for exposure is materially shortened.

Inverse Current. The current produced in the secondary of an induction coil on the making or completion of the circuit of the primary. Inverse currents flow in the opposite direction to the original current.

Joule. The amount of energy employed in maintaining a current of 1 ampere for 1 second against a resistance of 1 ohm—10,000,000 ergs.

Kilowatt. 1000 watts.

Micro-Farad. Practical unit of capacity.

Milliampere. $\frac{1}{1000}$ of an ampere.

Milliamperemeter. An instrument for recording the strength of a current passing in fractions of an ampere.

Ohm. Practical unit of electrical resistance. It was decided (Paris Congress, 1884) that the legal ohm is the resistance offered by a column of mercury 106 cm. high, 1 square mm. in cross-section, having about the resistance of 100 metres of telegraph wire.

Ohm's Law. The strength of the current varies directly as the E.M.F. and inversely as the resistance of the circuit, or the current expressed in amperes is equal to the E.M.F. expressed in volts divided by the resistance expressed in ohms:

$$C = \frac{E}{R}.$$

The law was enunciated by Dr. G. S. Ohm, and is used for showing the relation between Electromotive Force, Resistance, and Current.

Oscilloscope. A vacuum tube, constructed so as to show whether a current is unidirectional or oscillatory, and in the latter case roughly in which direction the greater quantity of current is flowing.

Parallel. Cells are said to be parallel when the positive elements are all connected to each other, and the negative are similarly connected. The E.M.F. is only equal to the E.M.F. of one cell, but its internal resistance is diminished in proportion to the number of cells thus joined. See *Series*.

Pole Tester. Any device for readily determining the polarity of the current, *e.g.* wet blue litmus paper will turn red in contact with the positive pole from a galvanic battery; the red spot will become blue again on the application of the negative pole; or when the end tips are placed in water and a galvanic current is turned on, bubbles of hydrogen will rise from the negative side, while the positive tip will become blackened.

Potential = *potentia*, power, ready to act, but not yet acting. It is the condition of electrical tension of a body. This term holds the same relation to electricity that the term level does to gravity; just as water at a higher level tends to move to a point of lower level, so does the accumulation of electric energy, at that point in the circuit at which it is present in excess over any other point in the circuit, tend to seek that point in the circuit at which it is lowest, so that electrical equilibrium may be restored.

Ray, Röntgen or X. Rays emitted from the source of radiant energy excited by a discharge of electricity within a vacuum tube, not deviable by a magnet or refracting medium; they pass through opaque bodies, cause certain substances to fluoresce, affect a photographic plate like light rays, and they have peculiar effects upon living tissue, normal and pathological.

Rectifier. An apparatus which is used to transform an alternating current into what is practically a unidirectional current. There are several kinds of rectifiers, the simplest of which is the "aluminium cell."

Resistance. (*a*) That which opposes the current flow. (*b*) The ratio of E.M.F. to the current strength:

$$C = \frac{E}{R}.$$

Rheostat. An instrument for regulating the resistance of an electric current.

Rotary Converter. A machine similar in design to an ordinary continuous current generator, but provided with slip rings, connected to suitable points in the armature winding.

Sabouraud's Pastilles. Pastilles of light-green colour, called by Sabouraud tint A, which turned to an orange colour, called by Sabouraud tint B, on being exposed to X-rays, thus measuring the dose.

Self-Induction. Induction produced in a circuit by the induction of a current on itself at the make or break of the current therein.

Series. Cells are said to be in series when the positive element of one cell is connected with the negative element of the next cell, and so on. The electromotive force of the combination, measured from the positive pole of the first to the negative pole of the last, is thus increased, *e.g.* in a battery with three cells, each having an E.M.F. of 1·5, the total E.M.F. will be volt 4·5.

Supply, Unit of. Board of Trade unit.

Unit Megohm. 1,000,000 ohms.

Unit Micro-Farad. $\frac{1}{1,000,000}$ farad.

Unit Micro-Volt. $\frac{1}{1,000,000}$ volt.

Unit Milliampere. $\frac{1}{1000}$ ampere.

Vacuum Tube. Glass tubes or bulbs from which nearly all traces of gas have been removed.

Volt. The practical unit of E.M.F. An E.M.F. which would cause a current of 1 ampere to flow through a resistance of 1 ohm.

Voltmeter. An instrument for measuring difference of potential.

Watt. Is a volt-ampere, or unit of electrical force.

Zero Potential. The earth's potential.

A SHORT LIST OF SOME IMPORTANT BOOKS ON RADIOLOGY

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