PORTER (W. T.)

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W. T. PORTER

556.

FROM
THE JOURNAL OF EXPERIMENTAL MEDICINE
VOL. I, NO. 2, 1896

A NEW METHOD FOR THE STUDY OF THE INTRACARDIAC PRESSURE CURVE.

By W. T. PORTER.

(*From the Laboratory of Physiology in the Harvard Medical School.*)

The method about to be described secures a correct record of any part of the intracardiac pressure curve, for it meets the theoret-

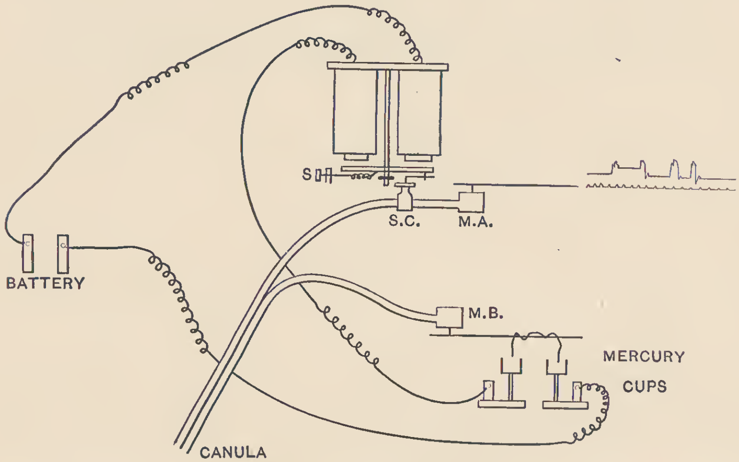

Fig. 1.—Scheme illustrating the arrangement of the apparatus. The meaning of the abbreviations is given in the text.

ical requirements of a perfect method, in that it employs an incompressible fluid and at the same time practically does away with the inertia error.

A short double canula is passed into the left ventricle through the subclavian artery and aorta. One tube of the canula is connected directly with a Hürthle membrane manometer (Fig. 1, M. B.) placed upside down. The recording lever of this manometer bears a wire, the ends of which are thrust into two mercury cups when the rising pressure in the inverted manometer carries the recording lever downward. When the pressure in the manometer

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falls, the lever withdraws the wire from the mercury cups. The passing of the wire into the mercury completes an electric circuit, and sends a current through a strong electro-magnet, the armature of which is arranged to open a stopcock (S. C.) placed between the second tube of the canula and a second membrane manometer (M. A.). When manometer B withdraws the wire from the mercury cups, thus breaking the circuit, the magnet releases the armature, and the latter is pulled back into its former position by the adjustable spring S, and so closes the stopcock. During the passage of the current through the magnet, manometer A, being placed by the opening of the stopcock in communication with the cavity of the ventricle, will write a pressure curve. The current, however, will pass through the magnet only when the wire of manometer B is in the mercury, hence the period during which manometer A can write the intraventricular pressure curve is controlled by manometer B.

If now manometer B is so adjusted that the ends of the wire are near the mercury during the diastole of the ventricle, the wire will dip into the mercury and open the stopcock soon after the beginning of the systolic rise of pressure, and manometer A will write the systolic curve almost from its commencement, as in Fig. 3. If, on the other hand, manometer B is so adjusted that the wire during diastole is far above the mercury, the rising intraventricular pressure will not succeed in bringing the wire into the mercury until toward the maximum of systole, and manometer A will write only the summit of the curve, as in the first curve of Fig. 6. Thus the portion of the intraventricular curve that is written by manometer A can be selected at the operator's pleasure merely by varying the position of the lever of manometer B, and thus varying the moment at which the wire shall make the circuit and open manometer A to the ventricle.

The satisfactory working of this method requires an exceedingly sensitive manometer, a stopcock that will open and close with great rapidity, and an entire absence of jar. The stopcock first employed was of glass. The rapidity with which it opened and closed was measured from a curve drawn by a writing point fastened on the armature of the electro-magnet that moved the stopcock (Fig. 2). It is seen that the time occupied by the entire stroke is less than a fiftieth of a second.

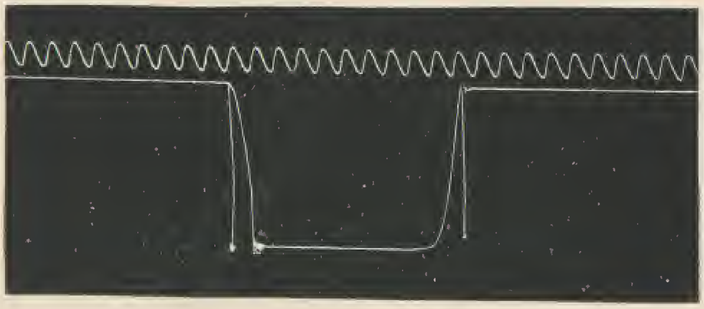

Fig. 2.—The original curves show greater fineness of line than appears in these reproductions. The upper curve was drawn by a rod making fifty double vibrations per second. The lower curve was drawn by a writing point fastened on the armature of the electro-magnet that moved the stopcock. The perpendiculars are drawn at the beginning and the end of the curves.

This glass stopcock was afterward replaced by one of brass,* the speed of which was considerably greater. The exact details of its construction, together with the arrangement and dimensions of the electro-magnet and the mercury cups, will be given in a subsequent paper, as the apparatus is now undergoing modifications by which, it is hoped, its efficiency will be increased.†

For present purposes it is enough to determine that the time lost between the making of the circuit by the wire of manometer B and the commencement of the curve of manometer A is inconsiderable. More than this is shown by the curve in Fig. 3.

An electric signal in the primary circuit wrote the upper curve. The next curve is that of the ventricular pressure, written by manometer A. The lower line marks the atmospheric pressure and the time in fifths of seconds. To the right is a graduation scale in intervals of 20 millimetres, Hg. The manometer. after being raised from

* Figs. 4, 5, and 6 were written with the brass cock and a wholly undamped manometer.

† The electro-magnetic stopcock is a slight modification of one invented by Prof. Bowditch and described by him in *Arbeiten aus der physiol. Anstalt zu Leipzig*, 1871, p. 143.

the atmospheric pressure to 160 millimetres, Hg., was placed again at the pressure of the atmosphere. The return to the abscissa is so perfect that the manometer line is entirely hidden in the line of the abscissa. It has already been said that the elevation in the upper line,

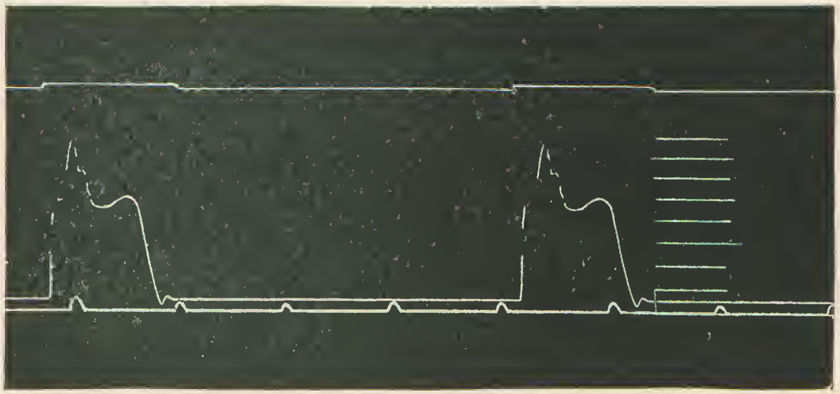

Fig. 3.—The elevation in the upper curve is the period during which the current flowed through the electro-magnet. The lowest line is the atmospheric pressure and the time in fifths of seconds. The graduation scale is in intervals of 20 millimetres, Hg.

written by the electric signal, records the period during which the current passed through the electro-magnet controlling the stopcock. The difference in the length of this elevation and the time during which the manometer wrote its curve is the time lost by the opening of the stopcock and the inertia of position (*Trägheit*) of the manometer, less the interval between the breaking of the circuit and the closure of the stopcock. The measurement of these different components will be given at another time. It is sufficient now to point out that the difference between the time during which the current flows through the stopcock and the time during which the curve is writing is too small to be of any practical importance.

If the manometer B is arranged to open the stopcock near the summit of intraventricular contraction, the first systolic rise after the experiment is begun will show a great inertia error in the curve written by manometer A, for this undamped manometer will be suddenly exposed to a high intracardiac pressure and the lever will be driven from near the atmospheric pressure to the height of intraventricular pressure in less time—that is, with greater velocity—than is the case in a manometer open at all times to the ventricular pressure. During the interval between the first and second contractions the pressure in the manometer A will not fall very far before the stopcock will close, leaving a high pressure in the manometer. For the manometer B, it will be remembered, was arranged to close the circuit near the summit of intraventricular pressure. It must, therefore, necessarily pull the circuit-making wire out of the mercury, and so break the circuit again, when its lever, in returning toward the abscissa, reaches a height above the abscissa equal to that at which the wire entered the mercury during the systolic rise of pressure. The second contraction of the ventricle will therefore find the pressure already high in manometer A. The rise that manometer A has now to record, when the stopcock opens, is not the difference between the pressure at the beginning and at the summit of systole, but between the summit and a point near the summit—in other words, a fraction of the total difference of pressure in systole. For example, the pressure in the manometer A may have been left at 100 millimetres, Hg.; during the next systolic rise the manometer will need to move, then,

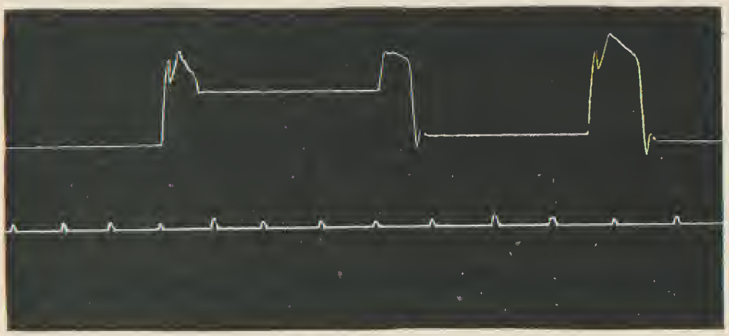

Fig. 4.—The upper line is the curve of intraventricular pressure. The lower line is the atmospheric pressure and the time in fifths of seconds.

only from 100 millimetres to the maximum intraventricular pressure—for example, 150 millimetres, Hg. The inertia error will thereby be much diminished, for the error accompanying the record of a difference of 50 millimetres is much less than that accompanying the record of 150 millimetres. Such a lessening of the inertia error is seen in the second curve of Fig. 4.

If now manometer B is so arranged that the stopcock opens when the intracardiac pressure has risen to 145 millimetres, Hg., within 5

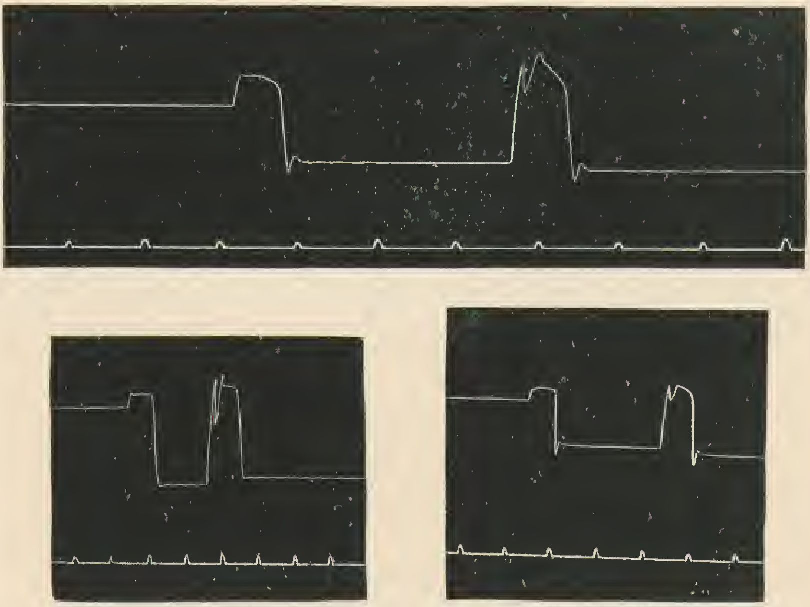

FIG. 5.—The upper line is intraventricular pressure. The lower line is the atmospheric pressure and the time in fifths of seconds. The inertia error diminishes according to the height above the atmospheric pressure at which the manometer begins to write.

millimetres, let us say, of the maximum, then manometer A, after a stroke or two has left its pressure at 145 millimetres, will have but 5 millimetres to record, and the inertia error accompanying the record of 5 millimetres is practically insignificant.

Thus the true summit of the intraventricular curve, unmarred by inertia errors, is written.

But this is not the only advantage of the new method. It is evident that the manometer that will give a useful record of a sudden difference of pressure of 150 millimetres, Hg., can not give a large excursion for a small increment of pressure. Practically it is not advisable to have the lever rise much above 1 millimetre for each increase of 10 millimetres, Hg., in pressure. Hence fine details, involving changes of a few millimetres, Hg., are apt to be obliterated by friction on the recording surface or other causes. But with the new method such details can be easily studied, because the manometer that is to write only a part of the intraventricular curve—5 millimetres, Hg., at the summit, for example—can afford to give a much larger excursion than the manometer that must record the whole curve.

When the mercury in the cups is at rest, the summits of the intraventricular pressure curves are written with almost schematic uniformity. If, however, the mercury in the cups is shaken by the current of water that is kept flowing over it in order to protect the wire

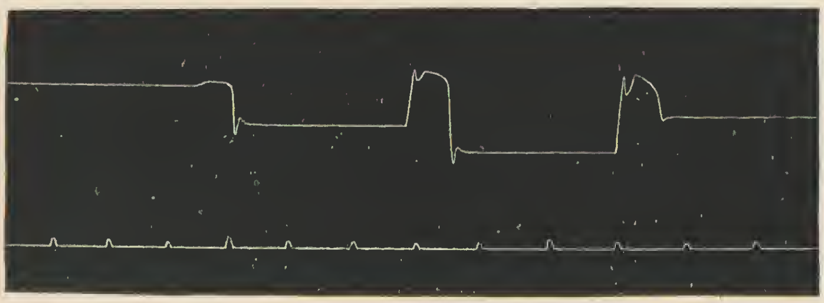

Fig. 6.—Upper curve, intraventricular pressure. Lower curve, atmospheric pressure and time in fifths of seconds. At the left only the very summit of the intraventricular pressure curve is written.

of manometer B from burning away, the make and break no longer occur at precisely the same height above the atmospheric pressure, and the interesting irregularities illustrated in several of the accompanying figures are seen.

It is evident that with this method the long-standing question as to the real form of the summit of the intracardiac pressure curve can be definitely answered. The nearer the summit the recording manometer begins to write, the more "plateau"-like the summit becomes and the less marked are those elevations the meaning of which has provoked so much discussion. They disappear entirely when the manometer writes the last few millimetres at the highest part of the curve, and the plateau then appears unvexed by inertia oscilla tions.

The summit of the normal intracardiac pressure curve is, as a rule, nearly parallel with the abscissa.

The method here described is applicable to any portion of the intracardiac or other pressure curves. With its aid the portion of the intraventricular curve lying next the atmospheric abscissa line can be studied with especial profit, and information of value, as I hope to show in my next communication, can be secured with regard to the subatmospheric pressures sometimes present in the ventricle.