TELEMEDICINE DURING AND BEYOND COVID-19

EDITED BY: Sonu Bhaskar, Maciej Banach, Robert Weissert, Shikha Mittoo and Alma Nurtazina

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TELEMEDICINE DURING AND BEYOND COVID-19

Topic Editors:
Sonu Bhaskar, Liverpool Hospital & South West Sydney Local Health District (SWSLHD), Sydney, Australia
Maciej Banach, Polish Mother's Memorial Hospital Research Institute, Poland
Robert Weissert, University of Regensburg, Germany
Shikha Mittoo, University of Toronto, Canada
Alma Nurtazina, Semey State Medical University, Kazakhstan

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Editorial: Telemedicine During and Beyond COVID-19

Sonu Bhaskar[1,2,3]*, *Alma Nurtazina*[1,4], *Shikha Mittoo*[1,5], *Maciej Banach*[1,6,7,8] and *Robert Weissert*[1,9]

[1] *Pandemic Health System REsilience PROGRAM (REPROGRAM) Global, Sydney, NSW, Australia,* [2] *Department of Neurology, Liverpool Hospital and South Western Sydney Local Health District, Sydney, NSW, Australia,* [3] *Neurovascular Imaging Laboratory & NSW Brain Clot Bank, Ingham Institute for Applied Medical Research, Sydney, NSW, Australia,* [4] *Department of Epidemiology and Biostatistics, Semey Medical University, Semey, Kazakhstan,* [5] *Department of Rheumatology, University Health Network and The University of Toronto, Toronto, ON, Canada,* [6] *Polish Mother's Memorial Hospital Research Institute, Lodz, Poland,* [7] *Cardiovascular Research Centre, University of Zielona Góra, Zielona Gora, Poland,* [8] *Department of Hypertension, Medical University of Lodz, Lodz, Poland,* [9] *Department of Neurology, University of Regensburg, Regensburg, Germany*

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Editorial on the Research Topic

Telemedicine During and Beyond COVID-19

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Edited by:
Luigi Lavorgna,
University of Campania Luigi Vanvitelli, Italy

Reviewed by:
Marcello Moccia,
University of Naples Federico II, Italy
Giovanna Borriello,
Sapienza Università di Roma, Italy

***Correspondence:**
Sonu Bhaskar
Sonu.Bhaskar@health.nsw.gov.au

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Telemedicine has been at the mainstay of patient care by offsetting the decline in outpatient visits during the Coronavirus disease 2019 (COVID-19) while providing critical patient continuity and limiting exposure to health systems and healthcare workers (1). However, there are concerns that the decline in outpatient visits has not been entirely offset by telemedicine, which may have consequences beyond the COVID-19 pandemic (2). The current Research Topic, "*Telemedicine during and beyond COVID-19,*" presents a collection of articles on telemedicine during and beyond COVID-19. The COVID-19 pandemic is causing an unprecedented public health crisis impacting healthcare systems, healthcare workers, and communities. The COVID-19 Pandemic Health System REsilience PROGRAM (REPROGRAM) consortium is an independent not-for-profit think-tank of international healthcare physicians, researchers, and policymakers formed to champion the safety of healthcare workers, policy development, and advocacy for global pandemic preparedness and action with a focus on advocacy and building capacity in under-resourced settings [Bhaskar et al. (a), (3)].

In addition to presenting an overview on disparities in telemedicine globally [Bhaskar et al. (a)], and across various medical specialties [Bhaskar et al. (b)], including teleneurology in Sub-Saharan Africa (Adebayo et al.), it also explores the current and potential applications of technologies such as artificial intelligence and robotics in designing futuristic telemedicine (Bhaskar, Bradley, Sakhamuri et al.). A study by Sinha et al. report on the implementation and evaluation of a video visit program at an academic practice in New York (USA) demonstrating promise for telemedicine in the primary care settings during COVID-19.

During the initial phase of the pandemic, acute shortages in global medical supplies were reported. An article in the current topic presents a model to profile critical medical stockpiles and improve the medical supply chain through the use of technologies such as advanced analytics and blockchain (Bhaskar, Tan et al.). Indeed, the provision of adequate medical supplies such as personal protective equipments (PPEs) and mechanical ventilators are warranted to mitigate the risks to healthcare workers and health systems and build capacity for future infectious disease outbreaks. Moreover, COVID-19 disrupted traditional medical education and training (Sharma and Bhaskar). This has led to the integration of telemedicine into medical education and training. The telemedicine enabled medical education system may continue beyond COVID-19 especially

in providing mental health support to medical students in general, and especially those from vulnerable backgrounds.

On another tangent, Lehner et al. from Germany, share their experiences on an online blog in assisting psychiatric patients, who have been rendered increasingly vulnerable due to social isolation and loneliness due to lockdown measures, during COVID-19. The ongoing and future mental health toll due to COVID-19 calls for increased attention, where telepsychiatry has a potential role to play as it has been received favorably by patients during various phases of COVID-19 lockdown (4). Merianos et al. present perspectives on the use of telemedicine toward tobacco cessation and prevention in rural areas during COVID-19. Seifert et al. provide key recommendations on mitigating the digital divide in delivering telemedicine to elderly patients in long-term care facilities, which have been severely impacted during the COVID-19. Interestingly, given the focus on telerehabilitation, apropos to which Stasolla et al. present an assistive-technologies based approach in supporting patients with neurological conditions and communication difficulties. COVID-19 has adversely impacted the provision and access of healthcare services to chronic disease patients (5), including those with acute and chronic neurological conditions (3, 6).

In conclusion, despite the broadening scope of telemedicine and rapid roll-out during the COVID-19, systemic issues such as organizational readiness, including digital maturity, licensing, regulatory hurdles, reimbursements, ability to be used by all groups, including the oldest and those with disabilities, infrastructural issues and geographical and digital disparities in telemedicine adoption warrant urgent attention [Bhaskar et al. (a); Bhaskar et al. (b)]. Future efforts should pivot around increasing telemedicine access and provision to those from marginalized communities and under-resourced settings (7). Telemedicine could play an important role in expanding the outreach to remote areas and those from vulnerable backgrounds (8, 9), as well as to developed and under-developed nations carrying a disproportionate burden of vulnerable communities [Bhaskar et al. (a)]. This should be complemented with efforts to standardize telemedicine care and/or workflows using common tools for the clinical examination which could improve telemedicine practice and quality of care (10). The increasing use and expansion of telemedicine are likely to persist beyond the COVID-19; therefore, building equitable telehealth systems should be central to our preparedness and public health response for the future, especially in the advent of a future pandemic.

AUTHOR'S NOTE

The COVID-19 pandemic is causing an unprecedented public health crisis impacting healthcare systems, healthcare workers, and communities. The COVID-19 Pandemic Health System REsilience PROGRAM (REPROGRAM) consortium is formed to champion the safety of healthcare workers, policy development, and advocacy for global pandemic preparedness and action.

AUTHOR CONTRIBUTIONS

All authors discussed the results and recommendations and contributed to the final manuscript.

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We would like to dedicate this work to our healthcare workers who have died due to COVID-19 while serving the patients at the frontline and to those who continue to serve during these challenging times.

REFERENCES

1. Patel SY, Mehrotra A, Huskamp HA, Uscher-Pines L, Ganguli I, Barnett ML. Trends in outpatient care delivery and telemedicine during the COVID-19 pandemic in the US. *JAMA Intern Med.* (2021) 181:388–91. doi: 10.1001/jamainternmed.2020.5928
2. Rapaport L. *Telemedicine Offsets Some Drop in US Outpatient Visits During COVID-19: Medscape*. (2020). Available online at: https://www.medscape.com/viewarticle/941080
3. Bhaskar S, Bradley S, Israeli-Korn S, Menon B, Chattu VK, Thomas P, et al. Chronic neurology in COVID-19 era: clinical considerations and recommendations from the REPROGRAM consortium. *Front Neurol.* (2020) 11:664. doi: 10.3389/fneur.2020.00664
4. Yellowlees P, Nakagawa K, Pakyurek M, Hanson A, Elder J, Kales HC. Rapid conversion of an outpatient psychiatric clinic to a 100% virtual telepsychiatry clinic in response to COVID-19. *Psychiatr Serv.* (2020) 71:749–52. doi: 10.1176/appi.ps.202000230
5. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) settings: recommendations from the REPROGRAM consortium. *Front Cardiovasc Med.* (2020) 7:112. doi: 10.3389/fcvm.2020.00112
6. Bhaskar S, Sharma D, Walker AH, McDonald M, Huasen B, Haridas A, et al. Acute neurological care in the COVID-19 era: the pandemic health system REsilience PROGRAM (REPROGRAM) consortium pathway. *Front Neurol.* (2020) 11:579. doi: 10.3389/fneur.2020.00579
7. Bhaskar S, Rastogi A, Menon KV, Kunheri B, Balakrishnan S, Howick J. Call for action to address equity and justice divide during COVID-19. *Front Psychiatry.* (2020) 11:559905. doi: 10.3389/fpsyt.2020.559905
8. Katzow MW, Steinway C, Jan S. Telemedicine and health disparities during COVID-19. *Pediatrics.* (2020) 146:e20201586. doi: 10.1542/peds.2020-1586
9. Lin S, Sattler A, Smith M. Retooling primary care in the COVID-19 era. *Mayo Clin Proc.* (2020) 95:1831–4. doi: 10.1016/j.mayocp.2020.06.050
10. Moccia M, Lanzillo R, Brescia Morra V, Bonavita S, Tedeschi G, Leocani L, et al. Assessing disability and relapses in multiple sclerosis on tele-neurology. *Neurol Sci.* (2020) 41:1369–71. doi: 10.1007/s10072-020-04470-x

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Telemedicine as the New Outpatient Clinic Gone Digital: Position Paper From the Pandemic Health System REsilience PROGRAM (REPROGRAM) International Consortium (Part 2)

Sonu Bhaskar[1,2,3,4]*, *Sian Bradley*[1,5], *Vijay Kumar Chattu*[1,6,7], *Anil Adisesh*[1,6,7], *Alma Nurtazina*[1,8], *Saltanat Kyrykbayeva*[1,8], *Sateesh Sakhamuri*[1,9], *Sebastian Moguilner*[1,10], *Shawna Pandya*[1,11], *Starr Schroeder*[1,12], *Maciej Banach*[1,13,14,15] *and Daniel Ray*[1,16]

[1] *Pandemic Health System REsilience PROGRAM (REPROGRAM) Consortium, REPROGRAM Telemedicine Sub-committee, Sydney, NSW, Australia,* [2] *Department of Neurology, Liverpool Hospital and South Western Sydney Local Health District, Sydney, NSW, Australia,* [3] *Neurovascular Imaging Laboratory & NSW Brain Clot Bank, Ingham Institute for Applied Medical Research, Sydney, NSW, Australia,* [4] *South Western Sydney Clinical School, The University of New South Wales, UNSW Medicine, Sydney, NSW, Australia,* [5] *The University of New South Wales (UNSW) Medicine Sydney, South West Sydney Clinical School, Sydney, NSW, Australia,* [6] *Department of Medicine, University of Toronto, Toronto, ON, Canada,* [7] *St. Michael's Hospital, Toronto, ON, Canada,* [8] *Department of Epidemiology and Biostatistics, Semey Medical University, Semey, Kazakhstan,* [9] *Department of Clinical Medical Sciences, The University of the West Indies, St. Augustine, Trinidad and Tobago,* [10] *Global Brain Health Institute, Trinity College Dublin, Dublin, Ireland,* [11] *Alberta Health Services and Project PoSSUM, University of Alberta, Edmonton, AB, Canada,* [12] *Penn Medicine Lancaster General Hospital and Project PoSSUM, Lancaster, PA, United States,* [13] *Polish Mother's Memorial Hospital Research Institute (PMMHRI), Łódz, Poland,* [14] *Cardiovascular Research Centre, University of Zielona Gora, Zielona Gora, Poland,* [15] *Department of Hypertension, Medical University of Lodz, Łódz, Poland,* [16] *Farr Institute of Health Informatics, University College London (UCL) & NHS Foundation Trust, Birmingham, United Kingdom*

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Edited by:
Alberto Eugenio Tozzi, Bambino Gesù Children Hospital (IRCCS), Italy

Reviewed by:
David Charles Willis, Strides Toronto, Canada
Pekka Lahdenne, Helsinki University Central Hospital, Finland

***Correspondence:**
Sonu Bhaskar
sonu.bhaskar@health.nsw.gov.au

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Technology has acted as a great enabler of patient continuity through remote consultation, ongoing monitoring, and patient education using telephone and videoconferencing in the coronavirus disease 2019 (COVID-19) era. The devastating impact of COVID-19 is bound to prevail beyond its current reign. The vulnerable sections of our community, including the elderly, those from lower socioeconomic backgrounds, those with multiple comorbidities, and immunocompromised patients, endure a relatively higher burden of a pandemic such as COVID-19. The rapid adoption of different technologies across countries, driven by the need to provide continued medical care in the era of social distancing, has catalyzed the penetration of telemedicine. Limiting the exposure of patients, healthcare workers, and systems is critical in controlling the viral spread. Telemedicine offers an opportunity to improve health systems delivery, access, and efficiency. This article critically examines the current telemedicine landscape and challenges in its adoption, toward remote/tele-delivery of care, across various medical specialties. The current consortium provides a roadmap and/or framework, along with recommendations, for telemedicine uptake and implementation in clinical practice during and beyond COVID-19.

Keywords: coronavirus disease 2019, COVID-19, telemedicine, telerehabilitation, telepsychiatry, teleneurology

INTRODUCTION

Coronavirus disease 2019 (COVID-19) has challenged the status quo of how we approach, deliver, and receive modern medicine (1–4). According to the American Telemedicine Association, telemedicine is defined as "the remote delivery of healthcare services and clinical information using telecommunications technology" (5). It allows for patient care while minimizing the need for physical interaction, thus reducing infection transmission and healthcare facility burden. It can be utilized for ongoing management of chronic conditions, medication compliance, physician-to-patient consultation, and other remote services (3, 4). This can be leveraged to benefit broader populations through telehealth platforms and assisted technologies such as the Internet of things (IoT). Telemedicine and digital technologies demonstrate exceptional potential in improving access and delivery in remote settings. There is also an opportunity to exploit the power of artificial intelligence (AI) algorithms to design a better pandemic preparedness and response plan (6). Health systems have had to adapt to address emerging needs quickly, and many medical subspecialties have transitioned from in-person outpatient care to remote tele- or e-health.

Broadly, telehealth technologies can be deployed for targeted purposes relevant to a pandemic (7). Remote assessment of patients could be undertaken, circumventing visits to outpatient clinics or primary care providers. Patient continuity for those with chronic diseases is essential during a pandemic (3, 4). Such patients are also at high risk of infection and poor outcomes, including mortality, among COVID-19-positive patients (3). Notably, telemedicine also limits infection exposure to healthcare staff, can provide rapid access to subspecialists who are not immediately available in person, and allows for multidisciplinary team discussions. This is crucial in pandemic settings, as the safety of healthcare professionals is essential to ensure the sustainability of health systems to cater to emergent cases and maintain ongoing care. Patients with flu-like symptoms can be triaged, and telemonitoring using video surveillance could be considered for patients who are homebound such as the elderly or frail.

Telemedicine can increase access for certain populations who are challenged during limited healthcare facility visitation, stay-home orders, and quarantine, such as single parents, immunocompromised patients, and patients who rely on the assistance of others for transportation. Monitoring of patients along with remote delivery of home-based exercise, physiotherapy, psychological counseling, social work consultations, and speech and language interventions could be undertaken through telemedicine. Our previous work analyzed the status and deployment of telemedicine during COVID-19 across the geographical divide (Bhaskar et al., under review). In this article, we analyze the uptake of telemedicine across various medical subspecialties and organizational settings with a focus on the current COVID-19 pandemic and propose an operational roadmap for further integration of telemedicine or tele-technologies across health organizations.

TELEMEDICINE IN EMERGENCY CASES AND TRIAGE

As hospital systems become strained by the surge of COVID-19 patients, methods to improve the efficiency of emergency departments (EDs) are required, while maintaining standards of patient care. Telemedicine supplies a potential avenue for triage of critical cases. Remote and ambulatory monitoring of patients can allow for remote triage and assessment of emergencies such as acute myocardial infarction (MI), allowing patients to bypass the ED (8). Automated forward triage systems that use algorithms to categorize patients into risk groups could also be utilized, as ED physicians experience considerable time pressure. Current examples include the Multi Sources Healthcare Architecture (MHSA) algorithm and the Electronic Modified Early Warning Scorecard (9). Telemedicine has also been used to triage, expedite, and streamline the local COVID-19 screening process, thereby reducing the strain on healthcare facilities and practitioner exposure.

The New York Presbyterian Hospital, a world leader in digital health innovation, has demonstrated an effective method to reduce the burden of milder presentations (10). They established an ED-based Telehealth Express Care Service, in which after presentation and triage at the ED, patients with milder cases are taken into a private room for a teleconsultation with a physician. Prescriptions and patient instructions are then printed to the room, and the patient is discharged. This dramatically reduces ED waiting times and allows the hospital to deal with ever-increasing ED presentation numbers (10). As patients become anxious about ED infection risk, systems such as these are required, and patients need to be able to effortlessly contact EDs to query whether their symptoms require a presentation.

Telecardiology

Cardiology is one of the first specialties in which comprehensive telemedicine systems have been implemented. Monitoring of heart rhythm in patients with implanted or real-time wearable devices has allowed ECG with Holter monitoring, echocardiography records, and virtual auscultation. An emerging body of evidence suggesting cardiac involvement in COVID-19 patients has concerned cardiologists (3, 11). This includes cardiovascular complications such as cardiac injury, heart failure, myocarditis, pericarditis, vasculitis, and arrhythmias (12–14). Patients with pre-existing cardiovascular conditions who contract COVID-19 also experience inordinately poor outcomes, including a 5- to 10-fold rise in mortality (15). Due to the COVID-19 pandemic, the American College of Cardiology urgently updated its guidance on "Telehealth: Rapid Implementation for Your Cardiology Clinic," in which it encouraged remote monitoring and virtual visits of patients with cardiac problems (16). The development of prognostic models based on the recently launched new European register CAPACITY-COVID will help to understand the role of underlying cardiovascular disease (CVD) in patients with COVID-19 (17).

Virtual options can significantly increase efficiency compared to in-person doctor appointments (18). Notably, non-invasive

telemonitoring in patients with heart failure reduces all-cause mortality and number of hospitalizations, as well as improves the quality of life (19). In February 2020, the Italian Society of Cardiology published data on the implementation of telemedicine in CVD patients and reported crucial involvement of telemedicine in the prehospital triage for ST-elevated myocardial infarction (STEMI) cases and remote monitoring by primary care physicians (20). An American Heart Association (AHA) statement emphasized the role of telemedicine in pediatric cardiology through advanced video technologies like tele-echocardiography, fetal echocardiography in prenatal diagnosis, screening for congenital heart diseases, and confirmatory echo tests, external rhythm monitoring, catheterization laboratory, and personal tele-electrophysiology (21). Due to their comorbidity risk, efforts to prevent COVID-19 infection in CVD patients should be undertaken seriously by reducing hospital admission and outpatient visits (3).

Treatment adherence is one of the significant issues in the long-term management of CVDs (22). The utilization of mobile phones through mobile health (Mhealth) can be one of the reliable potential solutions in this area through measures such as electronic pillboxes and text reminders (22). The unique advantage of portable devices and smartphones is the ability to reach most patients and caregivers. The widespread use of mobile technologies makes medical support more effective, faster, safer, and less expensive in both outpatient and inpatient settings (23). Mhealth can play an increasingly important role in cardiac care, extensively applied in triage, interventions, management, patient education, and rehabilitation. Telehealth solutions are critical now, as we aim to minimize patients at high and very high cardiovascular risk being hospitalized and provide ongoing support to CVD patients during the COVID-19 pandemic. In Poland, some other systems have been tested in heart failure patients (24, 25), including e-oximeter, allowing for monitoring of heart rhythm and blood saturation, which might help to decide whether those quarantined should be hospitalized during COVID-19.

Tele–Acute Neurology

Telemedicine allows for prompt assessment of potential emergent neurological cases and can aid those with hospital access issues and those requiring fast acute assessment (2, 4). Acute stroke outcomes are vastly impacted by the speed at which treatment is given, whether it be through tissue plasminogen activator (tPA), endovascular clot retrieval (EVT), or anti-hypertensives. During times of physician shortages, as doctors become re-purposed for COVID-19 purposes, rapid approaches to acute stroke management are needed (2). Reperfusion treatment viability through computed tomography (CT) can be assessed remotely, allowing reperfusion treatment using tPA and/or EVT to be efficiently undertaken. Furthermore, telemedicine can be utilized to determine which patients require an urgent transfer from non-EVT-capable hospitals to EVT-capable hospitals (26). A program developed in Germany known as TRANSIT-stroke, in which rural hospitals established a telemedicine network, saw an improvement in patient outcomes as neurological assessment was made faster, treatments were issued within the required timeframe, and 24 h neurologist access was enabled (27). Similarly, successful programs have been undertaken worldwide, such as telestroke programs in Hawaii and South California (28). There is also evidence to suggest that patients who receive acute stroke assessment through telemedicine do not perceive decreased physician empathy compared to those who receive physical consultation (29). This somewhat relieves concerns about impaired patient–physician connection through telemedicine. While telemedicine decreases the time it takes to analyze head CTs, more work is needed to ensure that this benefit applies equally across different telestroke programs (30).

Mobile stroke units (MSUs) go beyond this to provide CT scanners and stroke personnel within an ambulance vehicle. Such programs exist in locations such as Melbourne (Australia), various states in the US, and Hamburg and Berlin (Germany), among others (31). MSUs improve acute ischemic stroke outcomes by reducing the time to reperfusion; however, further development is needed in the treatment of hemorrhagic stroke. Telemedicine could also allow CT assessment of mild traumatic brain injuries (such as concussions). This can help to determine if the patient requires transfer to a major hospital or can be treated locally and will also allow for post-concussion checkups (32).

TELEMEDICINE IN CRITICAL CARE AND RESPIRATORY MANAGEMENT WITH AN EMPHASIS ON COVID-19

Vulnerable patients who require respiratory management and/or critical care are at increased COVID-19 risk due to their impaired state and require effective management with the aid of technology (33). In 2019, the Society of Critical Care Medicine (SCCM) Tele-ICU Committee in the United States published an update on developments in telehealth critical care (TCC) (34). They described three emerging trends in TCC: hub-and-spoke structure in which a central hub provides remote technical support, administrative support, and integration to a network of hospitals; decentralized structures in which consultations and patient reviews will be made on a case-by-case and request basis between two sites; and a hybrid structure in which a centralized structure exists but direct contact between spokes can be made for, e.g., specialist consultations. Barriers to TCC included cost and reimbursement issues, lack of responsibility for individual hospitals, and legislative issues (34).

A 2012 systematic review and meta-analysis of telemedicine in the US intensive care unit (ICU) setting demonstrated decreased mortality and length of hospital stay with telemedicine incorporation (35). However, a statistical difference between an active model or high-intensity passive model, in which continuous patient telemonitoring is conducted, and a low-intensity passive model, in which only teleconsultation with an intensivist is conducted, was not ascertained and is an area for further research (35). Patients with respiratory issues are at higher risk of COVID-19 severe infections due to issues such as ventilator reliance and decreased cough function (33). This includes patients with chronic respiratory

conditions such as chronic obstructive pulmonary disease (COPD), bronchial asthma, interstitial lung diseases, as well as chronic neurological conditions such as neuromuscular diseases (33, 36). Telemedicine aids respiratory patients through data collection, such as monitoring of vitals and ventilator status, and by transmitting these data for constant monitoring. In the case of under-resourced or under-developed critical care units in low and middle-income countries (LMICs) (Bhaskar et al., under review), frequent international tele-education can serve to upskill doctors and spread critical care knowledge, such as ventilator management (37).

CHRONIC DISEASE, PRIMARY CARE, AND THE NEED TO FOCUS ON NON-ACUTE CARE

Patients with non-acute diseases require ongoing support and cannot be neglected during COVID-19 times (1, 3, 4, 33). Studies have shown that telemedicine can lead to similar outcomes as face-to-face delivery of care in the management of patients with heart failure, hypertension, and diabetes (38, 39). Ongoing monitoring of these patients is required to prevent acute manifestations, hospitalization, or disease progression (3, 4). The differences within medical subspecialties and individual patients need to be considered, rather than broadly implementing uniform telemedicine approaches across all departments. For example, infectious disease cases can be complicated and require careful consideration of patient history and investigation findings. In these cases, asynchronous consultations, in which the physician reviews data before supplying patient recommendations, will be helpful (40). In other fields such as neurology, cardiology, and endocrinology, real-time, interactive consultations might be more applicable (3, 4).

Patients with neuromuscular issues are particularly at risk due to COVID-19 (4). Patients with motor neuron disease (MND)/amyotrophic lateral sclerosis (ALS) are among those who experience considerable disability and will require multidisciplinary telehealth (4). Types of telehealth include tele-advice, teleconsultation, tele-prescription, videoconferencing, home-based self-monitoring, and remote non-invasive-ventilation (NIV) monitoring. Videoconferencing involves consultation with a health professional, home-based self-monitoring involves taking one's own measurements and submitting them to a physician, and remote NIV monitoring involves remote monitoring of the patient's NIV data (41). The use of telehealth with ALS patients has been shown to be associated with positive benefits such as reasonable adoption rates, personalized data, and efficient consultations (42). Other movement disorders such as Parkinson's disease (PD) also require ongoing multidisciplinary care (43). Established programs such as the Ontario Telemedicine Network, the ParkinsonNet infrastructure in the Netherlands, and that of Kaiser Permanente in the US all display the ability to integrate telehealth into PD patient care (44). Areas for growth include the reimbursement of nursing homes that utilize telemedicine, acceptance by patients and physicians, and reimbursement of at-home telemedicine programs (44). Furthermore, global partnerships can increase international telehealth integration. For example, the International Parkinson and Movement Disorders Society Africa Section, established in the USA, launched a 5-year program to deliver specialist care to disadvantaged areas in Africa using WhatsApp™. Diagnosis of PD could also be aided by telehealth, with the Unified Parkinson's Disease Rating Scale (UPDRS) and Montreal Cognitive Assessment (MoCA) for PD both being able to be performed remotely (45). Such tele-tools have also been recently proposed in the times of COVID-19 for familial hypercholesterolemia patients, who require continuous monitoring of their health due to lifelong high levels of cholesterol and increased CVD risk (46). In migraine and headache patients, telemedicine could be used to assess new headache profiles for possible COVID-19 symptomology or standard outpatient consultations (4, 47).

Cancer patients are another group at risk of COVID-19 infection due to their immunosuppressed states, which could have fatal outcomes subsequent to infection (48–52). Oncologists would use telemedicine for ongoing monitoring and compliance with cancer patients (49, 51). This could be useful in monitoring adverse reactions to ongoing chemo- or radiotherapy, as well as to identify patients who might be at high risk of emergent medical attention, such as those at risk of venous thromboembolism. Cancer patients could also be offered multidisciplinary care, including psychological interventions, physiotherapy, and specialized interventions such as mindfulness training, to improve the overall quality of life (49). Overall, telemedicine offers opportunities for cancer patients to access specialist care in the comfort of their homes. Approaches to the use of telemedicine and mobile technologies in increasing access to novel drugs or interventions through clinical trials should be expeditiously pursued. Telemedicine could also be used in palliative care and end-of-life planning involving patients' carers, family, and multidisciplinary care team (53). Teledermatology is another promising perspective in the diagnosis and monitoring of skin lesions, including cancer (54).

Non-acute ophthalmological telemedicine has been implemented for retinal scans relating to diabetic retinopathy, retinopathy of prematurity, and other non-acute retinal monitoring (55). Fundus scanning and optical coherence tomography imaging are being sent to remote trained healthcare practitioners (HCPs) for evaluation and additionally are being evaluated by AI analysis using deep learning. These non-acute services are also being utilized locally by emergency and urgent care services to a certain extent (55).

Chronic patients must adhere to medications during this time and should not stop treatment regimens without consulting their physician (3, 4). Patients taking immunosuppressants, steroids, or pain medications may be concerned about their COVID-19 risk, and contact with their physicians needs to be ensured. Adherence to medications can be monitored through Mhealth and telehealth means (56). Such examples include digital adherence technologies (DATs) or electronic directly observed therapy (eDOT) for patients with tuberculosis (56). Measures include ingestible sensors, video observation, digital pillboxes, and smartphone applications and have been trialed in China, India, Belarus, and the US (56, 57).

IDENTIFYING THOSE WITH BULBAR AND RESPIRATORY WEAKNESS

The European Respiratory Society (ERS) task force has described the implementation of remote home mechanical ventilation and physical therapy for patients with chronic respiratory disorders (58). The emphasis is on promoting common standards of clinical criteria as well as analyzing the cost/benefit ratio and evaluating reimbursing rules to implement in different countries (58). Tele diagnosis uses patient data to aid remote diagnosis and can be utilized to identify those with bulbar and respiratory weakness. Telemedicine strategies such as electronic inhalers, chipped nebulizers, self-monitoring through apps, and text reminders increase medicine compliance in patients with asthma, COPD, and cystic fibrosis (CF) (59). Furthermore, the diagnosis of COPD through telemedicine means such as spirometry tracing and teleconsultation provides an opportunity to utilize technology to increase patient care. Further studies are needed to stratify which patients, in terms of severity, will be best suited to a telemedicine management approach. Another area of potential growth is in using AI algorithms to determine developing COPD exacerbations (60). Telemedicine for asthmatics tends to be more focused on treatment compliance and self-monitoring and can be useful in helping patients learn more about their disease, such as recognizing patterns of asthma triggers (61). Other barriers to care include the risk that patient data may be manipulated, networks potentially becoming compromised, and inconclusive data on the benefit of telehealth on specific diseases such as COPD (62).

Obstructive sleep apnea (OSA) is one such disease in which remote monitoring can be utilized to prevent patients from having to spend time in a sleep clinic or respiratory clinic (63). Home polysomnography devices can be used to track patients' breathing and oxygen levels; however, further work is needed to lower the rate of false negatives to the level of in-person sleep clinics (63). A 2018 prospective study of 780 patients used a portable spirometer, with Bluetooth capabilities and connected to a mobile phone application, to trace results and connect the patient to a physician for analysis (64). This allowed the patient's breathing difficulties to be assessed and categorized as asthma, COPD, or normal breathing function (64). This study shows promising results for remote diagnosis of chronic breathing conditions; however, it does not preclude the need for future testing in some more complicated cases. Other smartphone applications have utilized microphones and questionnaires to analyze and detect breathing difficulties associated with other pulmonary conditions such as coughs and lung cancer (65). COVID-19 could impose severe stress on sleep clinics and may limit in-laboratory polysomnography sleep studies for OSA assessments and diagnosis. Home-based tele-polysomnography for OSA assessment could be explored so that the delayed diagnosis and the associated impact on patients could be minimized.

Patients with OSA often require continuous positive airway pressure (CPAP) while sleeping to improve symptoms and achieve proper rest (66). In order to see sustained results, patients need to use CPAP for at least 4 h at night, combined with lifestyle changes such as weight reduction and smoking cessation (66). Low adherence to CPAP remains a continuous problem for OSA patients due to lack of motivation, discomfort, loud noise, and claustrophobia (67). Telehealth provides an opportunity to increase CPAP adherence by monitoring device output data and patient self-tracking of lifestyle factors. When usage falls, the patient can be contacted to discuss their reasons for low adherence and to motivate them to continue use (68).

Telemedicine could be used to monitor bulbar function in patients with a compromised bulbar function such as ALS (4, 69). The rapid decline in bulbar function could be captured using technologies that are useful in delivering specialist multidisciplinary care (69). Other diseases in which bulbar function may be impaired include myasthenia gravis, spinal–bulbar muscular dystrophy, and riboflavin transporter deficiency (4, 70–72).

TELEMEDICINE-ASSISTED FOLLOW-UP AND REHABILITATION

Telemedicine can aid with rehabilitation following acute incidents such as stroke and traumatic brain injury (TBI) (2, 4), as well as chronic conditions that require ongoing rehabilitation efforts such as COPD, CVD, diabetes, and obesity (3). Stroke telerehabilitation programs involving consultations, exercises, games, and therapy aspects have shown positive outcomes such as improving patients' functional abilities and mental health (4). Other benefits include increasing patient motivation and ease due to being in a home setting (73). It is important that patients receive enough support in areas such as technical setup and troubleshooting. The Telerehabilitation in Heart Failure Patients (TELEREH-HF) trial in Poland demonstrated that a 9-week hybrid comprehensive telerehabilitation (HCTR) program consisting of remote monitoring of training at patients' homes was well-tolerated (24, 25). However, the positive effects of the intervention didn't translate into improvement in clinical outcomes over a follow-up period of 12–24 months in comparison to standard care (24).

A 2018 systematic review similarly found that telerehabilitation allowed for equal or more significant patient outcomes than center-based rehabilitation programs in stroke (74). Furthermore, wearable devices can be used in the rehabilitation of various neurological diseases such as stroke, PD, multiple sclerosis, and TBI. Inactivity is associated with various comorbidities and is often a result of chronic neurological disease or acute accident recovery. Remote monitoring through wearable devices can track activity, gait, and any falls throughout rehabilitation (75).

TBI can result in cognitive issues such as sleep disturbance, photophobia, memory, and behavioral changes (76). It is crucial that patients are not discharged without a follow-up plan. A neuropsychological test battery in the few years following moderate-to-severe brain injury and inpatient rehabilitation is vital to assess any cognitive decline and plateau. During COVID-19 times, it is necessary to move outpatient testing of this sort to remote delivery, wherever feasible and while

maintaining efficacy. The Brief Test of Adult Cognition (BTACT) has been shown to be effective over the telephone in patients with TBI to assess cognitive state (77). Remote monitoring of physical activity by physiotherapists and patient consultation with neurologists can also be achieved through telemedicine. However, clear guidelines for rehabilitation management and evidence of efficacy through different delivery systems are lacking (78).

Pulmonary rehabilitation is essential for patients with chronic respiratory issues such as COPD and can be achieved through telehealth measures such as monitoring, consultation, and education (79). This is important in COPD, as potential exacerbations need to be monitored, and lower levels of rehabilitation access are associated with increased rates of hospitalization (79). Additionally, personal movement tracking devices involving accelerometers are helpful in tracking patient exercise, which is an essential area of pulmonary rehabilitation (80). Telehealth rehabilitation still faces major hurdles, however, such as cost-effectiveness, patient training, and the lack of regulatory frameworks surrounding personal health devices (80).

TELEMEDICINE IN PALLIATIVE CARE

According to the WHO, about 40 million people annually need palliative care, and only 14% of them receive it (81). The importance of primary healthcare in palliative care was highlighted by the first WHO global resolution on palliative care in 2014. The Project ECHO (Extension for Community Healthcare Outcomes), as one of the examples, shows the potential of telemedicine in the training of patients, their family members, and medical workers in palliative care (82, 83). The training of palliative care via telemedicine/telehealth for outpatients in primary care will increase the coverage and quality of both care and life for these patients. Telehealth, including mobile applications, plays a role in making patients more adherent to both pharmacological and non-pharmacological therapies; in remote monitoring of clinical parameters such as cardiovascular and respiratory system function; as well as in monitoring of diet and physical activity. Given the overload of respiratory diseases and the flu-like presentations in routine practice, telemedicine offers an alternative that is particularly relevant in the COVID-19 era.

TELEMEDICINE/TELEHEALTH APPLICATION IN MENTAL HEALTH

Mental health support to frontline health workers, patients, and carers will be crucial, as long isolation, lack of social interaction, as well as anxiety over one's own and others' health will take a toll on well-being (2–4, 84). Psychotherapy, psychiatry, and counseling are easily converted to a teleconference format through platforms (such as—but not limited to—Zoom™ and Skype™) and should be utilized by frontline health workers, patients, and carers where necessary (85). Anecdotal evidence also suggests that patients experiencing paranoid, anxiety, or post-traumatic stress disorders, who may be particularly affected by the COVID-19 climate (84), may feel more comfortable undergoing telepsychiatry over in-person psychiatry. Online delivery will further help to resolve issues such as lack of access to practitioners in rural settings and cultural and linguistic barriers (86). Furthermore, psychoeducation and mental well-being advice can be leveraged through smartphone apps and digital outreach programs (87). These services will become increasingly crucial in the pandemic setting, as physical isolation and frontline work pose both access issues and mental health stressors. The ethics of such teleservices needs to be ensured, with patient confidentiality, referral and billing practices, and physician eligibility being upheld (88). Psychiatrists, psychotherapists, and psychologists need to ensure that they are maintaining their own mental health during this time, with programs such as professional supervision being of help (4).

TELEHEALTH/TELEMEDICINE FOR THE ELDERLY

In 2018, nearly one-fifth of the European population was aged over 65 years old (89). An aging population has put significant pressure on public spending; therefore, telemedicine can improve the scale and efficiency of delivery and ongoing management of elderly patients. Elderly patients with mild cognitive impairment or dementia who might be at high risk of an acute condition should be identified using mobile technologies and telemedicine, and telemedicine solutions for the elderly should be easy to use and possibly automatic (4). This would avoid unnecessary burdens to public health facilities. Telemedicine can also be used to act as an interface of the local nursing care staff, carers, and patients with medical specialists. Elderly patients will benefit from remote allied health delivery. Patients who have had a recent surgery could be monitored at home or in nursing care facilities, preventing extended hospital stays. Elderly patients with diagnosed mental health conditions could also benefit from telemedicine. However, self-efficacy and digital literacy presumably have a significant impact on the uptake of telehealth among the elderly (90).

Recent data from the US confirm that the most vulnerable age group for COVID-19 is people over 65 years old, and the highest mortality is observed in those aged 85 and older (91). In Ontario, Canada (as well as in Italy and the US), 54% of deaths related to COVID-19 occurred in retirement homes and long-term care (92, 93). Strict zero-visitation policies have had debilitating effects for some elderly patients, particularly those with dementia (4). Telemedicine has been utilized to connect family members with these patients to prevent further decline in mental status and provide comfort. This is useful, as family members have voiced concerns that physically distanced visits such as through windows may further confuse their loved ones.

Telehealth allows continual monitoring of vitals, physical examination, ongoing clinical management, and communication with patients. In elderly patients with limited accessibility, telemedicine could provide an alternative, easy-to-access service. Elderly patients often suffer from social isolation, and telehealth can bring a sense of community. Furthermore, by using AI, falls can be detected among elderly patients (94). AI can provide personalized medicine solutions to help identify patients at risk of

harm. Primary healthcare physicians and nursing homes should watch for signs of depression in the elderly, particularly as it has been shown that telemedicine is competent in managing depressive symptoms in the elderly (95).

TELEHEALTH/TELEMEDICINE FOR CONGREGATE SETTINGS

Telemedicine can be useful in delivering interventions in congregate settings (96, 97). Challenges in congregate settings include high population density, limited mobility, built environment issues, and limited access to health. This can make the prevention and management of COVID-19 onerous while preserving human rights and ethical issues. Some of the potential target populations include refugees and migrants (96), those living in incarceration, orphanages, old-age homes, or childcare centers; and schools. These populations are especially vulnerable to infection such as COVID-19, where an outbreak can have facility-wide implications and adverse health consequences and fatality. A simulation study on the possible impact of COVID-19 outbreak in a Bangladeshi refugee camp found a dire need for dramatic increases in healthcare capacity and infrastructure (97). Existing approaches to control an outbreak, should it occur, would not be practically feasible, necessitating innovative solutions as well as novel and untested strategies in humanitarian settings (97). Telepsychiatry to monitor and deliver interventions in congregate settings, especially among refugee populations living in resource-constrained areas (98, 99), could be an alternative when traditional therapy is not possible. Telepsychiatry programs for congregate settings should be developed, and further studies are needed to evaluate their long-term impact on patient monitoring and care (99, 100).

COST–BENEFIT ANALYSIS

Telemedicine systems are not novel concepts and have been used to good effect for programs such as forward triage in EDs, critical care monitoring, and physician communication. Existing systems will need to be reallocated, and innovations will be pushed through in order to provide care across all medical fields and to reduce hospital burden. This needs to be achieved within the constraints of funding, legislation, and supply-chain barriers. Temporary government funding will be necessary to roll out telemedicine to both rural and urban settings, as well as relaxations to legislation that allow practitioner reimbursement of telemedicine services (101). A study by Sayani et al., addressing the cost and time barriers in chronic disease management through telemedicine in LMICs, found telemedicine to be economically beneficial not only by reducing the socioeconomic barriers to cost and access but also by increasing the uptake of services (102). Another systematic review of studies conducted on costs of home-based telemedicine programs from 2000 to 2017 found that home telemedicine programs reduced care costs, although detailed cost data were either incomplete or not presented in detail (103). The data on the cost-effectiveness of telemedicine solutions in different medical areas remains inconsistent and confounded by many variables, including the type of disease and "digital maturity" of healthcare systems. However, in critical situations such as the COVID-19 pandemic, telemedicine is proven necessary, and costing, billing, and reimbursement solutions are needed.

REIMBURSEMENT OF ALL TELEHEALTH PROVIDERS

There are variations in reimbursement policies across regions and healthcare systems. One of the major barriers has been harmonizing a standard reimbursement policy that is acceptable to all stakeholders and sustainable. We recommend that an integrated framework involving public and private parties could help develop a less complicated and streamlined reimbursement structure. Notably, the adoption of a "flip the switch" health insurance strategy in North Carolina to reimburse telehealth visits "at parity" with conventional office visits for all healthcare providers and specialists is timely and essential. In the long term, the impact of these strategies on healthcare quality and healthcare costs needs further study. Healthcare providers must lead the way here in the COVID-19 crisis to explore innovative approaches such as B2B monitoring.

LIMITATIONS OF TELEMEDICINE

Certain limitations may act as roadblocks in the uptake, implementation, and scale-up of telemedicine and supporting technologies. Considerable training is required to ensure patients can familiarize themselves with video teleconsultations and the use of supportive technologies. Physicians also need targeted technical, clinical, and communication training based on their subspecialty needs. Issues of limited access to broadband and Internet facilities are an area that particularly limits the deployment of telemedicine in remote areas and under-resourced settings. Telehealth requires reliable broadband access, which is not always acceptable both for clinics in rural areas and for patients living in such areas. When using telemedicine technology, legal restrictions and a lack of clarity as to what is permitted are possible, and these restrictions force telemedicine providers to proceed with caution. Some conditions are not considered in the legislation of health systems. It is still not entirely clear whether virtual consultations and video surveillance will be fully paid in hospitals or will be evaluated as shorter visits so that the rates will be lowered. Physician licensing and stability of the telemedicine infrastructures are issues of relevance in under-resourced settings.

Several critical medical procedures cannot be replaced by telemedicine, nor can it be offered to everyone, and there are many excluded groups of patients, including those with deficiencies (e.g., deaf and blind patients) and elderly patients. The effectiveness of telemedicine relies on the possibilities of the implementation of these tools in the given hospital/healthcare system, preparations/training of physicians/nurses, and awareness of the patients.

TABLE 1 | Telemedicine across various medical subspecialties.

	Telemedicine studies	Outcome parameter
Telemedicine in emergency cases and triage	Brennan et al. (104)	Reduced average patient throughput time (from admission to discharge).
	Dharmar et al. (105)	Improved physician-rated quality of care.
Telecardiology	Molinari et al. (106)	Reduced hospitalizations in patients with suspected life-threatening cardiac events.
	Khader et al. (107)	Improvement in the quality of life 2 months after the first visit.
	Scalvini et al. (108)	Possible cost reduction due to increased appropriateness of hospital admission and of diagnostic testing.
	Sable et al. (109)	Positive impact on referral patterns and time management in pediatric cardiology practice without increasing the utilization of echocardiography.
Teleneurology	Capozzo et al. (110)	Feasible to triage amyotrophic lateral sclerosis (ALS) patients using telemedicine. Increase in practice outreach and efficiency, especially in COVID-19 times.
	Ohta et al. (111)	Significant improvement in the state and trait anxiety inventories (STAI) scores in Parkinson's disease (PD), ALS, and spinocerebellar degeneration (SCD) + multiple system atrophy (MSA) patients.
Tele–acute neurology	Medeiros de Bustos et al. (112)	Reduction in secondary interhospital transfers.
	Vatankhah et al. (113)	Immediate impact on clinical decisions.
	Lyerly et al. (114)	Telemedicine increased access to acute stroke care.
	Dharmasaroja et al. (115)	Telemedicine increased intravenous thrombolysis rates without compromising favorable and safety outcomes.
	Schwab et al. (116)	Comparable mortality rates and functional outcomes for telemedicine-linked community hospitals and stroke centers to the results from randomized trials.
Telemedicine in critical care and respiratory management	Yang et al. (117)	Telemedicine feasible to support acute management of children who present to community hospitals.
	Kuipers et al. (118)	Acceptable positive predictive value of the electronic inhalation monitoring devices (EIMDs) in patients with respiratory diseases.
Chronic disease and primary care	Orozco-Beltran et al. (119)	Telemonitoring program effective in reducing high risk for rehospitalization or an emergency department visit.
	Doñate-Martínez et al. (120)	Telemedicine program improved self-reported quality of life and decreased use of health resources in elderly patients with chronic diseases. High satisfaction levels also observed in patients on the program.
	Martín-Lesende et al. (121)	Telemonitoring of in-home patients with heart failure and/or chronic lung disease led to an increase in the percentage of patients with no hospital admissions. Trend toward reduced total and cause-specific hospitalizations and hospital stay.
	Palmieri et al. (122)	No significant impact of home-based telemonitoring program on all-cause hospitalization/mortality. Telemonitoring associated with higher patient compliance and achievement of therapeutic targets.
Identifying those with bulbar and respiratory weakness	Pinto et al. (123)	Home-based telemonitoring of non-invasive ventilation decreased healthcare utilization in patients with ALS.
	Paganoni et al. (124)	Video visits associated with marked adjusted cost savings for patients and institutions.
Telemedicine-assisted follow-up and rehabilitation	Rawstorn et al. (125)	Telehealth exercise-based cardiac rehabilitation is as effective as center-based rehabilitation for improving modifiable cardiovascular risk factors and functional capacity. *Note: Systematic review included 11 clinical trials.*
Telemedicine in palliative care	Kuntz et al. (126)	Electronic family (e-family) meetings to facilitate in-patient palliative care during coronavirus disease 2019 (COVID-19) pandemic feasible and well received by families.
	Nemecek et al. (127)	Telemedicine augmented palliative care feasible in patients with advanced care and their family carers. Significant reduction in anxiety levels in the telemedicine group vs. the standard care.
Telemedicine in mental health	Ruskin et al. (128)	Telepsychiatry and in-person treatment of depression have comparable outcomes. Equivalent levels of patient adherence, patient satisfaction, and healthcare cost.
	Salisbury et al. (129)	Telehealth service leveraging non-clinically-trained health advisers supporting patients in use of Internet resources was both acceptable and effective compared with usual care.
	O'Reilly et al. (128)	Clinical outcomes of telepsychiatry equivalent to standard of care.
	Chipps et al. (99)	Telepsychiatry programs are feasible in congregate settings.

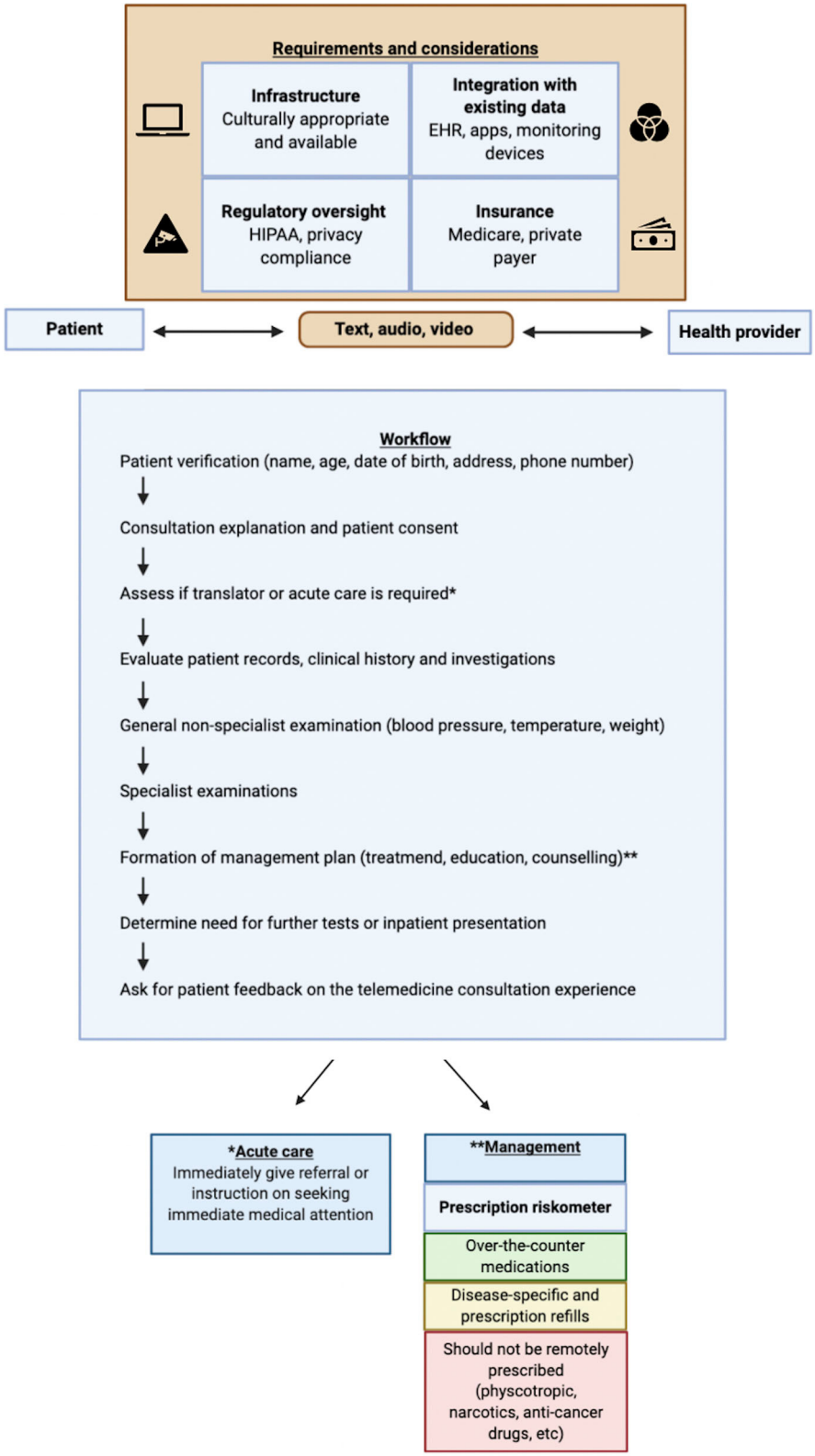

FIGURE 1 | Various requirements and considerations for streamlined telemedicine implementation and the Pandemic Health System REsilience PROGRAM (REPROGRAM) consortium workflow for routine teleconsultation and management of patients. Patients and healthcare providers can interact through telemedicine via

(Continued)

FIGURE 1 | text, audio, or video means. Effective telemedicine has several requirements, including culturally appropriate and available infrastructure; regulatory oversight and privacy compliance such as through the Health Insurance Portability and Accountability Act of 1996 (HIPAA); integration of technologies with existing data such as electronic health records (EHRs), apps, and monitoring devices; and insurance coverage such as Medicare or private-payer schemes. Credentialing on both sides is essential. The consultation should start with verification of the patient's identity through name, age, phone number, date of birth, and address. The physician should then clearly specify that this is a telemedicine consult and that no audio or video of the communication will be recorded. It is imperative that health record information is protected. The physician should then clearly and explicitly ask for consent, whether that be verbal, text, or video. At the start of the consultation, the physician should assess if acute care is required and make a cursory determination if telemedicine consultation is sufficient. If necessary, the physician should supply an immediate referral or advise the patient to seek immediate medical attention. During a typical consultation, the patient will be evaluated; and specific diagnostics and treatment would be recommended based on the assessment of the healthcare provider; and follow-up could be scheduled either in person or virtually. The physician should go through records, clinical history, and investigations including pathology and diagnostic reports, and obtain any additional information that the patient can provide. A general, non-specialist examination should be obtained, and any vital signs that the patient has the means to measure should be gathered.

Beyond this, when introducing technologies and measures to overcome gaps in the healthcare system, it is essential not to simply ask, "where are the gaps," but also to define the standards and ideals of care and continually iterate toward these ideals. As mentioned before, telemedical consultations do not approach the same level of fidelity that an in-person physical exam yields, between physical exams, body language, vocal intonations, and odors. As such, the fidelity of the technology involved with telemedical consults must continually iterate to reach the same level of fidelity and information that an in-person visit might yield. In this vein, virtual and augmented reality technologies, while evolving, hold promise for the future of telemedicine, particularly in envisioning a future in which high-fidelity physician and patient "avatars" may meet in a virtual space for a telemedical consult, replicating aspects of an in-person visit through immersive technologies.

CONCLUSION AND FUTURE DISCUSSION

COVID-19 has expedited the uptake of telemedicine across various specialties. The rapid move by various bodies, associations, and providers to use telemedicine in maintaining patient continuity while limiting COVID-19 risks of exposure to patients and healthcare workers will have a long-term impact well-beyond the current pandemic. Teleconsultation needs are varied across specialties, and therefore, specialty-specific guidelines and recommendations need to be developed. A scoping list of various telemedicine studies across medical subspecialties (telemedicine vs. standard care) has been provided in **Table 1**. A comprehensive workflow that critically profiles various telemedicine enablers has been proposed in **Figure 1**, and recommendations to improve various factors are listed in **Table 2**.

The proposed workflow (**Figure 1**) provides a practical telemedicine framework cognizant of relevant requirements and considerations, and a step-by-step pathway to streamlined telemedicine delivery. This could be used as a template (for further customization or adaptation) by individual medical subspecialties. Current challenges and recommendations to improve telemedicine include (130): (i) infrastructure capacity [formation and expansion of dedicated telemedicine units and workforce; cloud-based infrastructure to support telemedicine associated bandwidth traffic; liability, maintenance, and safety of telemedicine platforms; ongoing and regular maintenance and servicing of telemedicine hardware and software; awareness, education, and training to build confidence about telemedicine use among providers and consumers; compulsory telemedicine modules for medical students and continued professional development (CPD) workshops/courses for healthcare providers and medical informaticians/technologists; targeted courses aimed at re-skilling clinicians]; (ii) integration with existing data (standardized patient-specific information and consent form with telemedicine opt-in/out option); (iii) regulatory oversight issues (setup of telemedicine regulatory authority; accreditation/licensing of providers using telemedicine; guidelines for telemedicine use in inter-state and -nation settings; standardization of telemedicine related technologies and services with regulatory oversight, audit, and reporting; appropriate measures and oversight to protect privacy, security, and confidentiality of patient data; legal frameworks for telemedicine-specific information storage, sharing, and access); and (iv) insurance/payers (guidelines for telemedicine insurance; streamlined payment facilities for making and receiving payments; bundled services payments and insurance coverage).

Another important and emerging area is the use of text messaging [short message service (SMS) or multimedia message service (MMS)] as a model for service delivery (131–136). Text messaging has proven efficacious in diabetes self-management, smoking cessation, weight loss, physical activity, and adherence to medication regimens [such as in human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDS) patients who are on antiretroviral therapy] (132). A systematic review on text messaging interventions identified the following issues: identification of intervention characteristics, ensuring intervention effects last over a longer duration of time, and cost-effectiveness of these interventions (132). Issues of privacy and security are also poignant in this context. Nevertheless, text messaging offers potential benefit as a public health intervention toward chronic disease management (133–136), medication adherence, and secondary prevention (134).

Perceptions and experiences/satisfaction, regarding telemedicine services, of the patients and providers is important in improving telemedicine implementation, delivery, and impact (137–141). A systematic review on patient satisfaction with telemedicine highlighted methodological deficiencies in published studies (137). A study on patient and clinician experience with telemedicine found that virtual video visits may provide effective follow-up and increased convenience in comparison to routine in-person visits (139). Another study found a perception of patients with type 2 diabetes that

TABLE 2 | Various factors in telemedicine implementation and corresponding recommendations from the consortium.

Factors	Recommendations
Physician licensing	Facilitation and harmonization of inter-state licensing. Specialty-specific considerations for telemedicine-based care.
Bandwidth and infrastructure	Mobile phone–based Internet to avail of telemedicine, mobile Wi-Fi routers. The concerted effort through a public–private partnership involving key corporate players to improve Internet penetration in these pockets. Need domain experts to ensure that technologies are appropriately deployed.
Reimbursement, cost, and availability	Medicare-for-all coverage. The government needs to provide funding to develop platforms with minimal expenditure.
Clinician uptake	Specialty-specific training for clinicians and user-centric technology design considerations for easy and improved access.
Physician leadership	Quality control, regular re-skilling of professionals involved, ensuring infrastructure is being monitored. Collaboration between various stakeholders, including providers and insurance payers.
Language barriers	Technologies such as mobile apps that can be easily incorporated into telemedicine workflow.
Privacy	Blockchain-based platforms or applications could safeguard the privacy of physicians.
User training and technology deployment/access to hardware	Appropriate training addressing bias and nuances toward adopting telemedicine. Funding support and rapid deployment of telemedicine technologies across all providers. Provision for delivery of "bundled" telemedicine services. Public and private partnerships can act as enablers. Performance evaluation, ongoing assessment of patient and provider experiences, and adapting to address gaps.
Liability	Developing clear-cut guidelines to mitigate communication and technology-specific risks and liability. This should be done in consultation with providers, patients, and insurance/payers.
Geographical limitations	Use of low-bandwidth applications. Change management and culture-specific support.
Under-resourced settings	Technology-based health promotion, leveraging mobile health applications for community outreach, healthcare buddies who liaise with the community to educate and inform about technology and use. The WHO needs to take the lead in ensuring penetration of telemedicine in under-resourced locations in collaboration with philanthropic partners.
Complex cases	Evidence-based guidelines and workflow recommendations. Various boards, associations, and bodies should formalize standard protocols that could clearly delineate *do*s and *don't*s of clinical examination, diagnosis, and management using telemedicine technologies.
Patient–doctor relationship	Communication tool kit or handouts to improve user experience. Privacy and communication to patients that clinical data and consultations would remain confidential is critical.

telemedicine can improve their access to care (140). Further studies focusing on communication issues and the quality of interpersonal relationships during telemedicine consultations and how these factors affect healthcare delivery using this medium are required (137, 141).

Some specialist examinations, including neurologist consultation, can also be conducted. The American Academy of Neurology has issued guidelines for telemedicine consultation (142). Physicians can assess mental status; any visual, auditory, or cognitive deficits; comprehensive speech; cranial nerves; apparent tremors; and gait. Motor examinations can also be conducted with the aid of a caregiver in order to help ascertain strength, tone, reflexes, dermatome sensation, and cerebellar function. In such a case, consent must be gained from both the patient and the assistor. Special considerations may apply for pediatric patients or adults with intellectual disabilities. Based on the severity of symptoms, the patient may require a management plan, including specific treatment, health education, and counseling if necessary. Patients can be prescribed ongoing prescriptions, specific medications, or add-on medication to optimize regimes, given that there is no ambiguity about diagnosis and the medications are not dangerous. If there is any ambiguity about diagnosis, this must be recognized as a limitation of this mode of telemedicine, and documentation must be made. Further tests should be done or referred for in-person consultation if necessary. It should be noted that detailed examination of tone, strength, and reflexes; comprehensive eye examinations; and examinations that require specific maneuvers such as vestibular examinations should be avoided, as examination findings won't be accurate. These recommendations will also need to be adjusted according to individual state or federal legislation. The future of telemedicine beyond the current COVID-19 pandemic will depend on how we address existing challenges, building resilient health systems (2–4). Further randomized controlled trials to evaluate the long-term effects of telemedicine-based interventions in various patient populations should be planned. Telemedicine will play a major role as a "safety net" during the pandemic.

AUTHOR'S NOTE

The COVID-19 pandemic is causing an unprecedented public health crisis impacting healthcare systems, healthcare workers, and communities. The COVID-19 Pandemic Health System **RE**silience **PROGRAM** (**REPROGRAM**) consortium is formed to champion the safety of healthcare workers, policy development, and advocacy for global pandemic preparedness and action.

AUTHOR CONTRIBUTIONS

SBh devised the project, the main conceptual ideas, including the proposal for a new telemedicine workflow, the proof outline, and coordinated the writing and editing of the manuscript. SBh and SBr wrote the first draft of the manuscript. SBh encouraged SBr to

investigate and supervised the findings of this work. All authors discussed the results and recommendations and contributed to the final manuscript.

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REFERENCES

1. Klompas M. Coronavirus disease 2019 (COVID-19): protecting hospitals from the invisible. *Ann Int Med.* (2020) 172:619–20. doi: 10.7326/M20-0751
2. Bhaskar S, Sharma D, Walker AH, McDonald M, Huasen B, Haridas A, et al. Acute neurological care in the COVID-19 era: the pandemic health system REsilience PROGRAM (REPROGRAM) consortium pathway. *Front Neurol.* (2020) 11:579. doi: 10.3389/fneur.2020.00579
3. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key Strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) settings: recommendations from the REPROGRAM consortium. *Front Cardiovasc Med.* (2020) 7:112. doi: 10.3389/fcvm.2020.00112
4. Bhaskar S, Bradley S, Israeli-Korn S, Menon B, Chattu VK, Thomas P, et al. Chronic neurology in COVID-19 era: clinical considerations and recommendations from the REPROGRAM consortium. *Front Neurol.* (2020) 11:664. doi: 10.3389/fneur.2020.00664
5. American Telemedicine Association. *About Telemedicine*. Available online at: http://legacy.americantelemed.org/main/about/about-telemedicine/telemedicine-faqs (accessed April 16, 2020).
6. World Health Organization (WHO). *Artificial Intelligence for Good Global Summit. Director Generals'*. (2018). Available online at: https://www.who.int/dg/speeches/2018/artificial-intelligence-summit/en/ (accessed April 12, 2020).
7. Siwicki B. Telemedicine during COVID-19: Benefits, limitations, burdens, adaptation. *Healthcare IT News*. Available online at: https://www.healthcareitnews.com/news/telemedicine-during-covid-19-benefits-limitations-burdens-adaptation (accessed April 16, 2020).
8. Zimetbaum P, Goldman A. Ambulatory arrhythmia monitoring. *Circulation.* (2010) 122:1629–36. doi: 10.1161/CIRCULATIONAHA.109.925610
9. Napi NM, Zaidan AA, Zaidan BB, Albahri OS, Alsalem MA, Albahri AS. Medical emergency triage and patient prioritisation in a telemedicine environment: a systematic review. *Health Technol.* (2019) 9:679–700. doi: 10.1007/s12553-019-00357-w
10. Sharma R, Fleischut P, Barchi D. Telemedicine and its transformation of emergency care: a case study of one of the largest US integrated healthcare delivery systems. *Int J Emerg Med.* (2017) 10:21. doi: 10.1186/s12245-017-0146-7
11. Fried JA, Ramasubbu K, Bhatt R, Topkara VK, Clerkin KJ, Horn E, et al. The variety of cardiovascular presentations of COVID-19. *Circulation.* (2020) 141:1930–6. doi: 10.1161/CIRCULATIONAHA.120.047164
12. Shi S, Qin M, Shen B, Cai Y, Liu T, Yang F, et al. Association of cardiac injury with mortality in hospitalized patients with COVID-19 in Wuhan, China. *JAMA Cardiol.* (2020) 5:802–10. doi: 10.1001/jamacardio.2020.0950
13. Inciardi RM, Lupi L, Zaccone G, Italia L, Raffo M, Tomasoni D, et al. Cardiac involvement in a patient with coronavirus disease 2019 (COVID-19). *JAMA Cardiol.* (2020) 5:819–24. doi: 10.1001/jamacardio.2020.1096
14. Guo T, Fan Y, Chen M, Wu X, Zhang L, He T, et al. Cardiovascular implications of fatal outcomes of patients with coronavirus disease 2019 (COVID-19). *JAMA Cardiol.* (2020) 5:811–8. doi: 10.1001/jamacardio.2020.1017
15. Bonow RO, Fonarow GC, O'Gara PT, Yancy CW. Association of coronavirus disease 2019 (COVID-19) with myocardial injury and mortality. *JAMA Cardiol.* (2020). doi: 10.1001/jamacardio.2020.1105. [Epub ahead of print].
16. Bhatt A, Freeman A, Mullen B. *Telehealth: Rapid Implementation for Your Cardiology Clinic*. Available online at: https://www.acc.org/latest-in-cardiology/articles/2020/03/01/08/42/feature-telehealth-rapid-implementation-for-your-cardiology-clinic-coronavirus-disease-2019-covid-19 (accessed April 16, 2020).
17. Linschoten, Asselbergs FW. CAPACITY-COVID: a European Registry to determine the role of cardiovascular disease in the COVID-19 pandemic. *Eur Heart J.* (2020) 41:1795–6. doi: 10.1093/eurheartj/ehaa280
18. Kuehn BM. Telemedicine helps cardiologists extend their reach. *Circulation.* (2016) 134:1189–91. doi: 10.1161/CIRCULATIONAHA.116.025282
19. Inglis SC, Clark RA, Dierckx R, Prieto-Merino D, Cleland JG. Structured telephone support or non-invasive telemonitoring for patients with heart failure. *Cochrane Database Syst Rev.* (2015) Cd007228. doi: 10.1002/14651858.CD007228.pub3
20. Brunetti ND, Molinari G, Acquistapace F, Zimotti T, Parati G, Indolfi C, et al. 2019 Italian Society of Cardiology Census on telemedicine in cardiovascular disease: a report from the working group on telecardiology and informatics. *Open Heart.* (2020) 7:e001157. doi: 10.1136/openhrt-2019-001157
21. Satou GM, Rheuban K, Alverson D, Lewin M, Mahnke C, Marcin J, et al. Telemedicine in pediatric cardiology: a scientific statement from the American Heart Association. *Circulation.* (2017) 135:e648–78. doi: 10.1161/CIR.0000000000000478
22. Gandapur Y, Kianoush S, Kelli HM, Misra S, Urrea B, Blaha MJ, et al. The role of mHealth for improving medication adherence in patients with cardiovascular disease: a systematic review. *Eur Heart J Qual Care Clin Outcomes.* (2016) 2:237–44. doi: 10.1093/ehjqcco/qcw018
23. Honeyman E, Ding H, Varnfield M, Karunanithi M. Mobile health applications in cardiac care. *Int Cardiol.* (2014) 6:227–40. doi: 10.2217/ica.14.4
24. Piotrowicz E, Pencina MJ, Opolski G, Zareba W, Banach M, Kowalik I, et al. Effects of a 9-week hybrid comprehensive telerehabilitation program on long-term outcomes in patients with heart failure: the telerehabilitation in heart failure patients (TELEREH-HF) randomized clinical trial. *JAMA Cardiol.* (2020) 5:300–8. doi: 10.1001/jamacardio.2019.5006
25. Piotrowicz E, Piotrowicz R, Opolski G, Pencina M, Banach M, Zareba W. Hybrid comprehensive telerehabilitation in heart failure patients (TELEREH-HF): a randomized, multicenter, prospective, open-label, parallel group controlled trial-Study design and description of the intervention. *Am Heart J.* (2019) 217:148–58. doi: 10.1016/j.ahj.2019.08.015
26. Moustafa H, Barlinn K, Prakapenia A, Winzer S, Gerber J, Pallesen LP, et al. Endovascular therapy for anterior circulation large vessel occlusion in telestroke. *J Telemed Telecare.* (2019) 1357633x19867193. doi: 10.1177/1357633x19867193
27. Gabriel KMA, Jíru-Hillmann S, Kraft P, Selig U, Rücker V, Mühler J, et al. Two years' experience of implementing a comprehensive telemedical stroke network comprising in mainly rural region: the Transregional Network for Stroke Intervention with Telemedicine (TRANSIT-Stroke). *BMC Neurol.* (2020) 20:104. doi: 10.1186/s12883-020-01676-6
28. Chaffin HM, Nakagawa K, Koenig MA. Impact of Statewide Telestroke Network on acute stroke treatment in Hawai'i. *Hawaii J Health Soc Welf.* (2019) 78:280–6.
29. Cheshire WP, Barrett KM, Eidelman BH, Mauricio EA, Huang JF, Freeman WD, et al. Patient perception of physician empathy in stroke telemedicine. *J Telemed Telecare.* (2020) 1357633x19899237. doi: 10.1177/1357633x19899237

30. Swanson MB, Miller AC, Ward MM, Ullrich F, Merchant KAS, Mohr NM. Emergency department telemedicine consults decrease time to interpret computed tomography of the head in a multi-network cohort. *J Telemed Telecare*. (2019) 1357633X19877746. doi: 10.1177/1357633X19877746
31. Calderon VJ, Kasturiarachi BM, Lin E, Bansal V, Zaidat OO. Review of the mobile stroke unit experience worldwide. *Interv Neurol.* (2018) 7:347–58. doi: 10.1159/000487334
32. Yue JK, Upadhyayula PS, Avalos LN, Phelps RRL, Suen CG, Cage TA. Concussion and mild-traumatic brain injury in rural settings: epidemiology and specific health care considerations. *J Neurosci Rural Pract.* (2020) 11:23–33. doi: 10.1055/s-0039-3402581
33. Barker-Davies RM, O'Sullivan O, Senaratne KPP, Baker P, Cranley M, Dharm-Datta S, et al. The Stanford Hall consensus statement for post-COVID-19 rehabilitation. *Br J Sports Med*. (2020) 54:949–59. doi: 10.1136/bjsports-2020-102596
34. Subramanian S, Pamplin JC, Hravnak M, Hielsberg C, Riker R, Rincon F, et al. Tele-critical care: an update from the society of critical care medicine tele-ICU committee. *Crit Care Med.* (2020) 48:553–61. doi: 10.1097/CCM.0000000000004190
35. Wilcox ME, Adhikari NK. The effect of telemedicine in critically ill patients: systematic review and meta-analysis. *Crit Care.* (2012) 16:R127. doi: 10.1186/cc11429
36. Ambrosino N, Makhabah DN, Sutanto YS. Tele-medicine in respiratory diseases. *Multidisc Respir Med.* (2017) 12:9. doi: 10.4081/mrm.2017.232
37. Ambrosino N, Vagheggini G, Mazzoleni S, Vitacca M. Telemedicine in chronic obstructive pulmonary disease. *Breathe.* (2016) 12:350. doi: 10.1183/20734735.014616
38. Flodgren G, Rachas A, Farmer A, Inzitari M, Shepperd S. Interactive telemedicine: effects on professional practice and health care outcomes. *Cochr Database Syst Rev*. (2015) 9:CD002098. doi: 10.1002/14651858.CD002098.pub2
39. Katsiki N, Banach M, Mikhailidis DP. Lipid-lowering therapy and renin-angiotensin-aldosterone system inhibitors in the era of the COVID-19 pandemic. *Arch Med Sci.* (2020) 16:485–9. doi: 10.5114/aoms.2020.94503
40. Tande AJ, Berbari EF, Ramar P, Ponamgi SP, Sharma U, Philpot L, et al. Association of a remotely offered infectious diseases eConsult service with improved clinical outcomes. *Open Forum Infect Dis.* (2020) 7:ofaa003. doi: 10.1093/ofid/ofaa003
41. Helleman J, Kruitwagen ET, van den Berg LH, Visser-Meily JMA, Beelen A. The current use of telehealth in ALS care and the barriers to and facilitators of implementation: a systematic review. *Amyotroph Lateral Scler Frontotemporal Degener.* (2020) 21:167–82. doi: 10.1080/21678421.2019.1706581
42. Helleman J, Van Eenennaam R, Kruitwagen ET, Kruithof WJ, Slappendel MJ, Van Den Berg LH, et al. Telehealth as part of specialized ALS care: feasibility and user experiences with "ALS home-monitoring and coaching". *Amyotroph Lateral Scler Frontotemporal Degener.* (2020) 21:183–92. doi: 10.1080/21678421.2020.1718712
43. Klein BC, Busis NA. COVID-19 is catalyzing the adoption of teleneurology. *Neurology.* (2020) 94:903–4. doi: 10.1212/WNL.0000000000009494
44. Achey M, Aldred JL, Aljehani N, Bloem BR, Biglan KM, Chan P, et al. The past, present, and future of telemedicine for Parkinson's disease. *Mov Disord.* (2014) 29:871–83. doi: 10.1002/mds.25903
45. Katz M. Telehealth increases access to palliative care for people with Parkinson's disease and related disorders. *Ann Palliat Med.* (2020) 9(Suppl. 1):S75–9. doi: 10.21037/apm.2019.11.12
46. Banach M, Penson PE, Fras Z, Vrablik M, Pella D, Reiner Ž, et al. Brief recommendations on the management of adult patients with familial hypercholesterolemia during the COVID-19 pandemic. *Pharmacol Res.* (2020) 158:104891. doi: 10.1016/j.phrs.2020.104891
47. Szperka CL, Ailani J, Barmherzig R, Klein BC, Minen MT, Halker Singh RB, et al. Migraine care in the era of COVID-19: clinical pearls and plea to insurers. *Headache.* (2020) 60:833–42. doi: 10.1111/head.13810
48. Yeoh CB, Lee KJ, Rieth EF, Mapes R, Tchoudovskaia AV, Fischer GW, et al. COVID-19 in the cancer patient. *Anesth Anal.* (2020) 131:16–23. doi: 10.1213/ANE.0000000000004884
49. Weinkove R, McQuilten ZK, Adler J, Agar MR, Blyth E, Cheng AC, et al. Managing haematology and oncology patients during the COVID-19 pandemic: interim consensus guidance. *Med J Aust.* (2020) 212:481–9. doi: 10.5694/mja2.50607
50. Xia Y, Jin R, Zhao J, Li W, Shen H. Risk of COVID-19 for patients with cancer. *Lancet Oncol.* (2020) 21:e180. doi: 10.1016/S1470-2045(20)30150-9
51. Lambertini M, Toss A, Passaro A, Criscitiello C, Cremolini C, Cardone C, et al. Cancer care during the spread of coronavirus disease 2019 (COVID-19) in Italy: young oncologists' perspective. *ESMO Open.* (2020) 5:e000759. doi: 10.1136/esmoopen-2020-000759
52. Liang W, Guan W, Chen R, Wang W, Li J, Xu K, et al. Cancer patients in SARS-CoV-2 infection: a nationwide analysis in China. *Lancet Oncol.* (2020) 21:335–7. doi: 10.1016/S1470-2045(20)30096-6
53. Sirintrapun SJ, Lopez AM. Telemedicine in cancer care. *Am Soc Clin Oncol Educ Book.* (2018) 38:540–5. doi: 10.1200/EDBK_200141
54. Chuchu N, Dinnes J, Takwoingi Y, Matin RN, Bayliss SE, Davenport C, et al. Teledermatology for diagnosing skin cancer in adults. *Cochrane Database Syst Rev*. (2018) 12:Cd013193. doi: 10.1002/14651858.CD013193
55. Chee RI, Darwish D, Fernandez-Vega A, Patel S, Jonas K, Ostmo S, et al. Retinal telemedicine. *Curr Ophthalmol Rep.* (2018) 6:36–45. doi: 10.1007/s40135-018-0161-8
56. Subbaraman R, de Mondesert L, Musiimenta A, Pai M, Mayer KH, Thomas BE, et al. Digital adherence technologies for the management of tuberculosis therapy: mapping the landscape and research priorities. *BMJ Glob Health.* (2018) 3:e001018. doi: 10.1136/bmjgh-2018-001018
57. Macaraig M, Lobato MN, McGinnis Pilote K, Wegener D. A national survey on the use of electronic directly observed therapy for treatment of tuberculosis. *J Public Health Manag Pract.* (2018) 24:567–70. doi: 10.1097/PHH.0000000000000627
58. Ambrosino N, Vitacca M, Dreher M, Isetta V, Montserrat JM, Tonia T, et al. Tele-monitoring of ventilator-dependent patients: a European Respiratory Society Statement. *Eur Respir J.* (2016) 48:648–63. doi: 10.1183/13993003.01721-2015
59. Kovacevic P, Dragic S, Kovacevic T, Momcicevic D, Festic E, Kashyap R, et al. Impact of weekly case-based tele-education on quality of care in a limited resource medical intensive care unit. *Crit Care.* (2019) 23:220. doi: 10.1186/s13054-019-2494-6
60. Blakey JD, Bender BG, Dima AL, Weinman J, Safioti G, Costello RW. Digital technologies and adherence in respiratory diseases: the road ahead. *Eur Respir J.* (2018) 52:1801147. doi: 10.1183/13993003.01147-2018
61. Vitacca M, Montini A, Comini L. How will telemedicine change clinical practice in chronic obstructive pulmonary disease? *Ther Adv Respir Dis.* (2018) 12:1753465818754778. doi: 10.1177/1753465818754778
62. Ambrosino N, Fracchia C. The role of tele-medicine in patients with respiratory diseases. *Expert Rev Respir Med.* (2017) 11:893–900. doi: 10.1080/17476348.2017.1383898
63. Bruyneel M. Telemedicine in the diagnosis and treatment of sleep apnoea. *Eur Respir Rev.* (2019) 28:180093. doi: 10.1183/16000617.0093-2018
64. Gurbeta L, Badnjevic A, Maksimovic M, Omanovic-Miklicanin E, Sejdic E. A telehealth system for automated diagnosis of asthma and chronical obstructive pulmonary disease. *J Am Med Inform Assoc.* (2018) 25:1213–7. doi: 10.1093/jamia/ocy055
65. Majumder S, Deen MJ. Smartphone sensors for health monitoring and diagnosis. *Sensors.* (2019) 19:2164. doi: 10.3390/s19092164
66. Pépin JL, Tamisier R, Hwang D, Mereddy S, Parthasarathy S. Does remote monitoring change OSA management and CPAP adherence? *Respirology.* (2017) 22:1508–17. doi: 10.1111/resp.13183
67. Turino C, de Batlle J, Woehrle H, Mayoral A, Castro-Grattoni AL, Gómez S, et al. Management of continuous positive airway pressure treatment compliance using telemonitoring in obstructive sleep apnoea. *Eur Respir J.* (2017) 49:1601128. doi: 10.1183/13993003.01128-2016
68. Munafo D, Hevener W, Crocker M, Willes L, Sridasome S, Muhsin Ma. A telehealth program for CPAP adherence reduces labor and yields similar adherence and efficacy when compared to standard of care. *Sleep Breath.* (2016) 20:777–85. doi: 10.1007/s11325-015-1298-4
69. Hobson E, Baird W, Bradburn M, Cooper C, Mawson S, Quinn A, et al. Process evaluation and exploration of telehealth in motor

neuron disease in a UK specialist centre. *BMJ Open.* (2019) 9:e028526. doi: 10.1136/bmjopen-2018-028526
70. Basiri K, Ansari B, Okhovat AA. Life-threatening misdiagnosis of bulbar onset myasthenia gravis as a motor neuron disease: How much can one rely on exaggerated deep tendon reflexes. *Adv Biomed Res.* (2015) 4:58. doi: 10.4103/2277-9175.151874
71. Chahin N, Klein C, Mandrekar J, Sorenson E. Natural history of spinal-bulbar muscular atrophy. *Neurology.* (2008) 70:1967–71. doi: 10.1212/01.wnl.0000312510.49768.eb
72. Jaeger B, Bosch AM. Clinical presentation and outcome of riboflavin transporter deficiency: mini review after five years of experience. *J Inherit Metab Dis.* (2016) 39:559–64. doi: 10.1007/s10545-016-9924-2
73. Chen Y, Chen Y, Zheng K, Dodakian L, See J, Zhou R, et al. A qualitative study on user acceptance of a home-based stroke telerehabilitation system. *Top Stroke Rehabil.* (2020) 27:81–92. doi: 10.1080/10749357.2019.1683792
74. Sarfo FS, Ulasavets U, Opare-Sem OK, Ovbiagele B. Tele-rehabilitation after stroke: an updated systematic review of the literature. *J Stroke Cerebrovasc Dis.* (2018) 27:2306–18. doi: 10.1016/j.jstrokecerebrovasdis.2018.05.013
75. Block VA, Pitsch E, Tahir P, Cree BA, Allen DD, Gelfand JM. Remote physical activity monitoring in neurological disease: a systematic review. *PLoS ONE.* (2016) 11:e0154335. doi: 10.1371/journal.pone.0154335
76. Martinez RN, Hogan TP, Lones K, Balbale S, Scholten J, Bidelspach D, et al. Evaluation and treatment of mild traumatic brain injury through the implementation of clinical video telehealth: provider perspectives from the Veterans Health Administration. *PM R.* (2017) 9:231–40. doi: 10.1016/j.pmrj.2016.07.002
77. Dams-O'Connor K, Sy KTL, Landau A, Bodien Y, Dikmen S, Felix ER, et al. The Feasibility of telephone-administered cognitive testing in individuals 1 and 2 years after inpatient rehabilitation for traumatic brain injury. *J Neurotrauma.* (2018) 35:1138–45. doi: 10.1089/neu.2017.5347
78. O'Neil J, van Ierssel J, Sveistrup H. Remote supervision of rehabilitation interventions for survivors of moderate or severe traumatic brain injury: a scoping review. *J Telemed Telecare.* (2019) 1357633x19845466. doi: 10.1177/1357633x19845466
79. Selzler AM, Wald J, Sedeno M, Jourdain T, Janaudis-Ferreira T, Goldstein R, et al. Telehealth pulmonary rehabilitation: a review of the literature and an example of a nationwide initiative to improve the accessibility of pulmonary rehabilitation. *Chron Respir Dis.* (2018) 15:41–7. doi: 10.1177/1479972317724570
80. Hernandez C, Mallow J, Narsavage GL. Delivering telemedicine interventions in chronic respiratory disease. *Breathe.* (2014) 10:198. doi: 10.1183/20734735.008314
81. World Health Organization (WHO). *Noncommunicable Diseases and their Risk Factors.* Available online at: https://www.who.int/ncds/management/palliative-care/en/ (accessed April 16, 2020).
82. Fisher E, Hasselberg M, Conwell Y, Weiss L, Padrón NA, Tiernan E, et al. Telementoring primary care clinicians to improve geriatric mental health care. *Popul Health Manag.* (2017) 20:342–7. doi: 10.1089/pop.2016.0087
83. White C, McIlfatrick S, Dunwoody L, Watson M. Supporting and improving community health services-a prospective evaluation of ECHO technology in community palliative care nursing teams. *BMJ Support Palliat Care.* (2019) 9:202. doi: 10.1136/bmjspcare-2015-000935
84. Blanco C, Wall MM, Olfson M. Psychological aspects of the COVID-19 pandemic. *J Gen Intern Med.* (2020). doi: 10.1007/s11606-020-05955-3
85. Chan S, Parish M, Yellowlees P. Telepsychiatry today. *Curr Psychiatry Rep.* (2015) 17:89. doi: 10.1007/s11920-015-0630-9
86. Fortney JC, Pyne JM, Turner EE, Farris KM, Normoyle TM, Avery MD, et al. Telepsychiatry integration of mental health services into rural primary care settings. *Int Rev Psychiatry.* (2015) 27:525–39. doi: 10.3109/09540261.2015.1085838
87. Chan S, Godwin H, Gonzalez A, Yellowlees PM, Hilty DM. Review of use and integration of mobile apps into psychiatric treatments. *Curr Psychiatry Rep.* (2017) 19:96. doi: 10.1007/s11920-017-0848-9
88. DeJong SM. Professionalism and technology: competencies across the tele-behavioral health and E-behavioral health spectrum. *Acad Psychiatry.* (2018) 42:800–7. doi: 10.1007/s40596-018-0947-x
89. European Commission. *2018 Ageing Report: Policy Challenges for Ageing Societies.* Available online at: https://ec.europa.eu/info/news/economy-finance/policy-implications-ageing-examined-new-report-2018-may-25_en (accessed June 18, 2020).
90. van Houwelingen CT, Ettema RG, Antonietti MG, Kort HS. Understanding older people's readiness for receiving telehealth: mixed-method study. *J Med Internet Res.* (2018) 20:e123. doi: 10.2196/jmir.8407
91. CDC. COVID-19 response team. severe outcomes among patients with coronavirus disease 2019 (COVID-19) - United States, February 12-March 16, 2020. *MMWR Morb Mortal Wkly Rep.* (2020) 69:343–6. doi: 10.15585/mmwr.mm6912e2
92. McMichael TM, Currie DW, Clark S, Pogosjans S, Kay M, Schwartz NG, et al. Epidemiology of Covid-19 in a long-term care facility in king county, Washington. *N Engl J Med.* (2020) 382:2005–11. doi: 10.1056/NEJMoa2005412
93. Booth R. *Half of Coronavirus Deaths Happen in Care Homes, Data from EU Suggests.* Available online at: https://www.theguardian.com/world/2020/apr/13/half-of-coronavirus-deaths-happen-in-care-homes-data-from-eu-suggests (accessed April 16, 2020).
94. Serpen G, Khan R. Real-time detection of human falls in progress: machine learning approach. *Proc Comput Sci.* (2018) 140:238–47. doi: 10.1016/j.procs.2018.10.324
95. Harerimana B, Forchuk C, O'Regan T. The use of technology for mental healthcare delivery among older adults with depressive symptoms: a systematic literature review. *Int J Ment Health Nurs.* (2019) 28:657–70. doi: 10.1111/inm.12571
96. Porritt A. *What Will Happen if Coronavirus Enters a Refugee Camp?* Available online at: https://www.unicef.org.au/blog/unicef-in-action/april-2020/coronavirus-refugees (accessed on June 17, 2020).
97. Truelove S, Abrahim O, Altare C, Lauer SA, Grantz KH, Azman AS, et al. The potential impact of COVID-19 in refugee camps in Bangladesh and beyond: a modeling study. *PLoS Med.* (2020) 17:e1003144. doi: 10.1371/journal.pmed.1003144
98. Hassan A, Sharif K. Efficacy of telepsychiatry in refugee populations: a systematic review of the evidence. *Cureus.* (2019) 11:e3984. doi: 10.7759/cureus.3984
99. Chipps J, Brysiewicz P, Mars M. Effectiveness and feasibility of telepsychiatry in resource constrained environments? A systematic review of the evidence. *Afr J Psychiatry.* (2012) 15:235–43. doi: 10.4314/ajpsy.v15i4.30
100. O'Reilly R, Bishop J, Maddox K, Hutchinson L, Fisman M, Takhar J. Is telepsychiatry equivalent to face-to-face psychiatry? Results from a randomized controlled equivalence trial. *Psychiatr Serv.* (2007) 58:836–43. doi: 10.1176/ps.2007.58.6.836
101. Smith AC, Thomas E, Snoswell CL, Haydon H, Mehrotra A, Clemensen J, et al. Telehealth for global emergencies: Implications for coronavirus disease 2019 (COVID-19). *J Telemed Telecare.* (2020) 26:309–13. doi: 10.1177/1357633X20916567
102. Sayani S, Muzammil M, Saleh K, Muqeet A, Zaidi F, Shaikh T. Addressing cost and time barriers in chronic disease management through telemedicine: an exploratory research in select low- and middle-income countries. *Ther Adv Chronic Dis.* (2019) 10:2040622319891587. doi: 10.1177/2040622319891587
103. Michaud TL, Zhou J, McCarthy MA, Siahpush M, Su D. Costs of home-based telemedicine programs: a systematic review. *Int J Technol Assess Health Care.* (2018) 34:410–8. doi: 10.1017/S0266462318000454
104. Brennan JA, Kealy JA, Gerardi LH, Shih R, Allegra J, Sannipoli L, et al. Telemedicine in the emergency department: a randomized controlled trial. *J Telemed Telecare.* (1999) 5:18–22. doi: 10.1258/1357633991932342

105. Dharmar M, Romano PS, Kuppermann N, Nesbitt TS, Cole SL, Andrada ER, et al. Impact of critical care telemedicine consultations on children in rural emergency departments. *Crit Care Med.* (2013) 41:2388–95. doi: 10.1097/CCM.0b013e31828e9824
106. Molinari G, Reboa G, Frascio M, Leoncini M, Rolandi A, Balzan C, et al. The role of telecardiology in supporting the decision-making process of general practitioners during the management of patients with suspected cardiac events. *J Telemed Telecare.* (2002) 8:97–101. doi: 10.1258/1357633021937541
107. Khader YS, Jarrah MI, Al-Shudifat AE, Shdaifat A, Aljanabi H, Al-Fakeh SI, et al. Telecardiology application in Jordan: its impact on diagnosis and disease management, patients' quality of life, and time- and cost-savings. *Int J Telemed Appl.* (2014) 2014:819837. doi: 10.1155/2014/819837
108. Scalvini S, Zanelli E, Volterrani M, Castorina M, Giordano A, Glisenti F. Potential cost reductions for the National Health Service through a telecardiology service dedicated to general practice physicians. *Ital Heart J Suppl.* (2001) 2:1091–7.
109. Sable CA, Cummings SD, Pearson GD, Schratz LM, Cross RC, Quivers ES, et al. Impact of telemedicine on the practice of pediatric cardiology in community hospitals. *Pediatrics.* (2002) 109:E3. doi: 10.1542/peds.109.1.e3
110. Capozzo R, Zoccolella S, Musio M, Barone R, Accogli M, Logroscino G. Telemedicine is a useful tool to deliver care to patients with Amyotrophic Lateral Sclerosis during COVID-19 pandemic: results from Southern Italy. *Amyotroph Lateral Scler Frontotemporal Degener.* (2020) 1–7. doi: 10.1080/21678421.2020.1773502
111. Ohta Y, Yamashita T, Hishikawa N, Sato K, Hatanaka N, Takemoto M, et al. Affective improvement of neurological disease patients and caregivers using an automated telephone call service. *J Clin Neurosci.* (2018) 56:74–8. doi: 10.1016/j.jocn.2018.07.006
112. Medeiros de Bustos E, Berthier E, Chavot D, Bouamra B, Moulin T. Evaluation of a French regional telemedicine network dedicated to neurological emergencies: a 14-year study. *Telemed J E Health*. (2018) 24:155–60. doi: 10.1089/tmj.2017.0035
113. Vatankhah B, Schenkel J, Fürst A, Haberl RL, Audebert HJ. Telemedically provided stroke expertise beyond normal working hours. The telemedical project for integrative stroke care. *Cerebrovasc Dis.* (2008) 25:332–7. doi: 10.1159/000118378
114. Lyerly MJ, Wu TC, Mullen MT, Albright KC, Wolff C, Boehme AK, et al. The effects of telemedicine on racial and ethnic disparities in access to acute stroke care. *J Telemed Telecare.* (2016) 22:114–20. doi: 10.1177/1357633X15589534
115. Dharmasaroja PA, Muengtaweepongsa S, Kommarkg U. Implementation of Telemedicine and Stroke Network in thrombolytic administration: comparison between walk-in and referred patients. *Neurocrit Care.* (2010) 13:62–6. doi: 10.1007/s12028-010-9360-3
116. Schwab S, Vatankhah B, Kukla C, Hauchwitz M, Bogdahn U, Fürst A, et al. Long-term outcome after thrombolysis in telemedical stroke care. *Neurology.* (2007) 69:898–903. doi: 10.1212/01.wnl.0000269671.08423.14
117. Yang CP, Hunt EA, Shilkofski N, Dudas R, Egbuta C, Schwartz JM. Can telemedicine improve adherence to resuscitation guidelines for critically Ill children at community hospitals? A randomized controlled trial using high-fidelity simulation. *Pediatr Emerg Care.* (2017) 33:474–9. doi: 10.1097/PEC.0000000000000653
118. Kuipers E, Poot CC, Wensing M, Chavannes NH, de Smet PA, Teichert M. Self-management maintenance inhalation therapy with eHealth (SELFIE): observational study on the use of an electronic monitoring device in respiratory patient care and research. *J Med Internet Res.* (2019) 21:e13551. doi: 10.2196/13551
119. Orozco-Beltran D, Sánchez-Molla M, Sanchez JJ, Mira JJ, ValCrònic Research G. Telemedicine in primary care for patients with chronic conditions: the ValCrònic Quasi-Experimental study. *J Med Inter Res.* (2017) 19:e400. doi: 10.2196/jmir.7677
120. Doñate-Martínez A, Ródenas F, Garcés J. Impact of a primary-based telemonitoring programme in HRQOL, satisfaction and usefulness in a sample of older adults with chronic diseases in Valencia (Spain). *Arch Gerontol Geriatr.* (2016) 62:169–75. doi: 10.1016/j.archger.2015.09.008
121. Martín-Lesende I, Orruño E, Bilbao A, Vergara I, Cairo MC, Bayón JC, et al. Impact of telemonitoring home care patients with heart failure or chronic lung disease from primary care on healthcare resource use (the TELBIL study randomised controlled trial). *BMC Health Serv Res.* (2013) 13:118. doi: 10.1186/1472-6963-13-118
122. Palmieri V, Pezzullo S, Lubrano V, Bettella S, Olandese M, Sorrentino C, et al. [Home-based telemonitoring of simple vital signs to reduce hospitalization in heart failure patients: real-world data from a community-based hospital]. *G Ital Cardiol.* (2011) 12:829–36. doi: 10.1714/996.10828
123. Pinto A, Almeida JP, Pinto S, Pereira J, Oliveira AG, de Carvalho M. Home telemonitoring of non-invasive ventilation decreases healthcare utilisation in a prospective controlled trial of patients with amyotrophic lateral sclerosis. *J Neurol Neurosurg Psychiatry.* (2010) 81:1238–42. doi: 10.1136/jnnp.2010.206680
124. Paganoni S, van de Rijn M, Drake K, Burke K, Doyle M, Ellrodt AS, et al. Adjusted cost analysis of video televisits for the care of people with amyotrophic lateral sclerosis. *Muscle Nerve.* (2019) 60:147–54. doi: 10.1002/mus.26606
125. Rawstorn JC, Gant N, Direito A, Beckmann C, Maddison R. Telehealth exercise-based cardiac rehabilitation: a systematic review and meta-analysis. *Heart.* (2016) 102:1183–92. doi: 10.1136/heartjnl-2015-308966
126. Kuntz JG, Kavalieratos D, Esper GJ, Ogbu N, Jr., Mitchell J, Ellis CM, et al. Feasibility and acceptability of inpatient palliative care E-family meetings during COVID-19 pandemic. *J Pain Symptom Manage.* (2020). doi: 10.1016/j.jpainsymman.2020.06.001
127. Nemecek R, Huber P, Schur S, Masel EK, Baumann L, Hoeller C, et al. Telemedically augmented palliative care: Empowerment for patients with advanced cancer and their family caregivers. *Wien Klin Wochenschr.* (2019) 131:620–6. doi: 10.1007/s00508-019-01562-3
128. Ruskin PE, Silver-Aylaian M, Kling MA, Reed SA, Bradham DD, Hebel JR, et al. Treatment outcomes in depression: comparison of remote treatment through telepsychiatry to in-person treatment. *Am J Psychiatry.* (2004) 161:1471–6. doi: 10.1176/appi.ajp.161.8.1471
129. Salisbury C, O'Cathain A, Edwards L, Thomas C, Gaunt D, Hollinghurst S, et al. Effectiveness of an integrated telehealth service for patients with depression: a pragmatic randomised controlled trial of a complex intervention. *Lancet Psychiatry.* (2016) 3:515–25. doi: 10.1016/S2215-0366(16)00083-3
130. Ateriya N, Saraf A, Meshram VP, Setia P. Telemedicine and virtual consultation: The Indian perspective. *Natl Med J India.* (2018) 31:215–8. doi: 10.4103/0970-258X.258220
131. Park LG, Howie-Esquivel J, Dracup K. A quantitative systematic review of the efficacy of mobile phone interventions to improve medication adherence. *J Adv Nurs.* (2014) 70:1932–53. doi: 10.1111/jan.12400
132. Hall AK, Cole-Lewis H, Bernhardt JM. Mobile text messaging for health: a systematic review of reviews. *Annu Rev Public Health.* (2015) 36:393–415. doi: 10.1146/annurev-publhealth-031914-122855
133. Zheng X, Spatz ES, Bai X, Huo X, Ding Q, Horak P, et al. Effect of text messaging on risk factor management in patients with coronary heart disease: the CHAT randomized clinical trial. *Circ Cardiovasc Qual Outcomes.* (2019) 12:e005616. doi: 10.1161/CIRCOUTCOMES.119.005616
134. Huo X, Spatz ES, Ding Q, Horak P, Zheng X, Masters C, et al. Design and rationale of the Cardiovascular Health and Text Messaging (CHAT) study and the CHAT-Diabetes Mellitus (CHAT-DM) study: two randomised controlled trials of text messaging to improve secondary prevention for coronary heart disease and diabetes. *BMJ Open.* (2017) 7:e018302. doi: 10.1136/bmjopen-2017-018302
135. Mehraeen E, Safdari R, Mohammadzadeh N, Seyedalinaghi SA, Forootan S, Mohraz M. Mobile-based applications and functionalities for self-management of people living with HIV. *Stud Health Technol Inform.* (2018) 248:172–9.
136. Mbuagbaw L, Mursleen S, Lytvyn L, Smieja M, Dolovich L, Thabane L. Mobile phone text messaging interventions for HIV and other chronic diseases: an overview of systematic reviews and framework for evidence transfer. *BMC Health Serv Res.* (2015) 15:33. doi: 10.1186/s12913-014-0654-6
137. Mair F, Whitten P. Systematic review of studies of patient satisfaction with telemedicine. *BMJ.* (2000) 320:1517. doi: 10.1136/bmj.320.7248.1517

138. Freir V, Kirkwood K, Peck D, Robertson S, Scott-Lodge L, Zeffert S. Telemedicine for clinical psychology in the Highlands of Scotland. *J Telemed Telecare.* (1999) 5:157–61. doi: 10.1258/1357633991933567
139. Donelan K, Barreto EA, Sossong S, Michael C, Estrada JJ, Cohen AB, et al. Patient and clinician experiences with telehealth for patient follow-up care. *Am J Manag Care.* (2019) 25:40–4.
140. Gordon HS, Solanki P, Bokhour BG, Gopal RK. "I'm not feeling like I'm part of the conversation" patients' perspectives on communicating in clinical video telehealth visits. *J Gen Intern Med.* (2020) 35:1751–8. doi: 10.1007/s11606-020-05673-w
141. Williams TL, May CR, Esmail A. Limitations of patient satisfaction studies in telehealthcare: a systematic review of the literature. *Telemed J e-Health.* (2001) 7:293–316. doi: 10.1089/153056201528 14700
142. American Academy of Neurology (AAn). *Telemedicine and COVID-19 Implementation Guide*. Available online at: https://www.aan.com/tools-and-resources/practicing-neurologists-administrators/telemedicine-and-remote-care/ (accessed on June 17, 2020).

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The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Implementation of Video Visits During COVID-19: Lessons Learned From a Primary Care Practice in New York City

Sanjai Sinha[1], Lisa M. Kern[1], Laura F. Gingras[1], Evgeniya Reshetnyak[1], Judy Tung[1], Fred Pelzman[1], Thomas A. McGrath[2] and Madeline R. Sterling[1]*

[1] Division of General Internal Medicine, Department of Medicine, Weill Cornell Medicine, New York, NY, United States, [2] Department of Medicine, Weill Cornell Medicine, New York, NY, United States

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Edited by:
Sonu Bhaskar, NSW Health Statewide Biobank, Sydney, NSW, Australia

Reviewed by:
Negman Walmore Alvarado Rivera, Universidad Nacional Tecnológica, Argentina
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***Correspondence:**
Sanjai Sinha
sas9169@med.cornell.edu

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Background: During the height of the coronavirus (COVID-19) pandemic, there was an unprecedented demand for "virtual visits," or ambulatory visits conducted *via* video interface, in order to decrease the risk of transmission.

Objective: To describe the implementation and evaluation of a video visit program at a large, academic primary care practice in New York, NY, the epicenter of the COVID-19 pandemic.

Design and participants: We included consecutive adults (age > 18) scheduled for video visits from March 16, 2020 to April 17, 2020 for COVID-19 and non-COVID-19 related complaints.

Intervention: New processes were established to prepare the practice and patients for video visits. Video visits were conducted by attendings, residents, and nurse practitioners.

Main measures: Guided by the RE-AIM Framework, we evaluated the Reach, Effectiveness, Adoption, and Implementation of video visits.

Key results: In the 4 weeks prior to the study period, 12 video visits were completed. During the 5-weeks study period, we completed a total of 1,030 video visits for 817 unique patients. Of the video visits completed, 42% were for COVID-19 related symptoms, and the remainder were for other acute or chronic conditions. Video visits were completed more often among younger adults, women, and those with commercial insurance, compared to those who completed in-person visits pre-COVID (all $p < 0.0001$). Patients who completed video visits reported high satisfaction (mean 4.6 on a 5-point scale [*SD*: 0.97]); 13.3% reported technical challenges during video visits.

Conclusions: Video visits are feasible for the delivery of primary care for patients during the COVID-19 pandemic.

Keywords: telemedicine, video visit, ambulatory care, implementation science, primary care, COVID-19

BACKGROUND

Shortly after its first confirmed case on March 1, 2020, New York City became the epicenter of the novel coronavirus, SARS-CoV-2, pandemic in the United States (1). As social distancing became a key public health strategy to minimize viral transmission, medical centers, and physician practices were urged to rapidly implement new models of healthcare delivery which met patients' needs, but also limited exposure risk (2). As a result, there was a demand for virtual care, especially video visits, as an alternative to traditional in-person care (3).

Although video visits have been previously used and have been found to be feasible (4), their adoption and utilization have been limited (5–7). As of 2019, only 8% of Americans had ever done a video visit with a physician (8). Reasons for low adoption rates had included: lack of reimbursement, inadequate digital infrastructure, and incompatible workflow (6, 9). For patients, language barriers and inadequate access to technology platforms and the internet (10, 11) were often cited as barriers to video visits (6).

Nevertheless, given the need to care for patients remotely during COVID-19, the demand for video visits increased, potentially outweighing many of these prior utilization barriers. Herein we report the experiences of one large, academic, urban primary care practice with implementing a video visit program during the COVID-19 pandemic in New York City. Using a modified version of the RE-AIM Framework (12), we report on the Reach, Effectiveness, Adoption, and Implementation of video visits in order to describe our experiences to other primary care practices across the country who may need to adopt a similar care model.

METHODS

Setting and Patient Population

This is a retrospective case study of consecutive adults scheduled for video visits during the 5-weeks period from Monday, March 16, 2020 to Friday, April 17, 2020 at Weill Cornell Internal Medicine Associates (WCIMA). WCIMA is a large, academic, hospital-based primary care practice of Weill Cornell Medicine and NewYork-Presbyterian Hospital (https://weillcornell.org/wcima). As a high-volume tertiary-care clinic, it averages 53,000 office visits per year and serves a diverse patient population (13). At WCIMA, 31 attending physicians, 11 nurse practitioners, and six registered nurses provide care, alongside 129 residents and interns. Because we report on the video visit technology itself, as well as the effectiveness of its implementation, this study is a Hybrid Type 2- Effectiveness Implementation design (14, 15).

Context: Limited Use of Video Visits Pre-COVID-19

Video visits were first introduced at WCIMA in September 2019. However, only a few providers utilized this technology with their patients. Barriers for use pre-COVID-19 included: limited understanding and training on the technology among providers and staff and uncertainty about how best to divide clinician time between video and in-person visits. To address these barriers, training sessions demonstrating how to schedule and perform video visits occurred during faculty meetings in the fall of 2019 and providers were asked to complete training modules. Despite these efforts, adoption remained low.

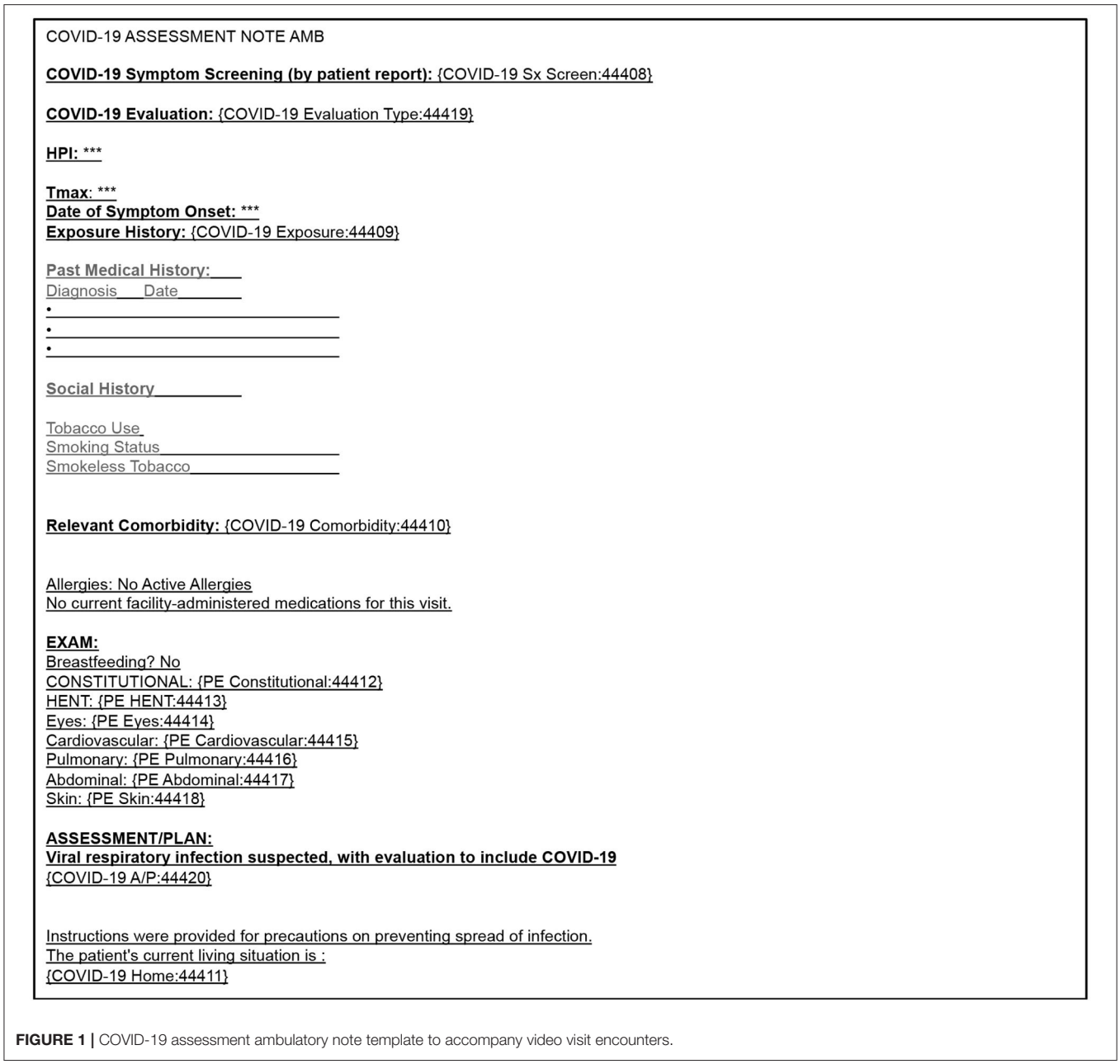
Developing Infrastructure for Video Visits During COVID-19

WCIMA utilized the Epic system for video visits [Epic Systems, Verona, WI]. Patients connected to video visits through a Weill Cornell Connect App on their smartphone (any brand) or tablet whereas providers conducted video visits through Epic Haiku (iPhone) or Epic Canto (iPad). The practice purchased iPads for providers without an iPhone or iPad to use. During or after visits, providers documented encounters using traditional Epic notes via their phone, tablet, or desktop.

To minimize COVID-19 transmission and the use of personal protective equipment, starting on March 16, 2020, the majority of care at WCIMA was transitioned to video visits. Providers conducted video visits for patients with COVID-19-like symptoms, as well as for patients with acute and chronic care needs. While providers were encouraged to maximize the use of video visits, they were permitted to conduct in-person visits for urgent complaints where they deemed a physical exam was needed. To guide providers on how to conduct video visits for COVID-19 and usual care, a group of physicians developed a Video Visit Handbook (**Appendix 1**). This handbook was updated twice during the study period to reflect rapidly changing clinical recommendations for the ambulatory management of COVID-19. Weill Cornell's Physician Organization Information Services (POIS) created an electronic health record template for COVID-19 assessments (**Figure 1**). Providers were asked to use this template for all COVID-19 related video and in-person visits. As shown in **Figure 1**, the template contained 10 structured data elements (free-text or drop-down) for the COVID-19 video visit. In addition, POIS developed smartphrases in Epic for patient instructions, based on CDC guidelines for COVID-19 including how to socially distance, and perform self-care monitoring. These smartphrases were developed in English and Spanish.

Video Visit Workflow During COVID-19

To prepare for the shift to video visits, starting on March 16, 2020, clinic staff received training on how to schedule patients for video visits, including how to teach patients to download and use the app. Each week during the study period, staff and providers reviewed upcoming scheduled visits for that week, and determined who should be seen in person and who could be converted to a video visit. Those eligible for a virtual visit but without access to a smart device and internet connection were offered a telephone visit. A hybrid scheduling model was used, in which providers had half-day sessions devoted to seeing their own patients virtually and others for which they were available for video visits with any patient in the practice, to maximize access. Similar to in-person visits, video visits were 20 min in duration, but could be longer at the discretion of the provider. Video visits took place Monday through Friday, with occasional Saturday visits. Providers conducted video visits from WCIMA offices or remotely. Practice administrators worked with hospital



COVID-19 ASSESSMENT NOTE AMB

COVID-19 Symptom Screening (by patient report): {COVID-19 Sx Screen:44408}

COVID-19 Evaluation: {COVID-19 Evaluation Type:44419}

HPI: ***

Tmax: ***
Date of Symptom Onset: ***
Exposure History: {COVID-19 Exposure:44409}

Past Medical History:
Diagnosis Date
•
•
•

Social History

Tobacco Use
Smoking Status
Smokeless Tobacco

Relevant Comorbidity: {COVID-19 Comorbidity:44410}

Allergies: No Active Allergies
No current facility-administered medications for this visit.

EXAM:
Breastfeeding? No
CONSTITUTIONAL: {PE Constitutional:44412}
HENT: {PE HENT:44413}
Eyes: {PE Eyes:44414}
Cardiovascular: {PE Cardiovascular:44415}
Pulmonary: {PE Pulmonary:44416}
Abdominal: {PE Abdominal:44417}
Skin: {PE Skin:44418}

ASSESSMENT/PLAN:
Viral respiratory infection suspected, with evaluation to include COVID-19
{COVID-19 A/P:44420}

Instructions were provided for precautions on preventing spread of infection.
The patient's current living situation is :
{COVID-19 Home:44411}

FIGURE 1 | COVID-19 assessment ambulatory note template to accompany video visit encounters.

compliance to understand billing procedures, and physicians were trained to document and bill for video visits in accordance with the new rules regarding broadened telehealth payment policies during COVID-19 from the Centers for Medicare and Medicaid Services (CMS) (16). Documentation of verbal consent from the patient to engage in a telemedicine visit was required in each note. The same evaluation and management codes and the same rules for determining level of service for in-person care were used for video visits.

As outlined in the Video Visit Handbook, a main goal of each video visit for COVID-19 was for providers to determine if patients could be managed safely at home with supportive care, if they needed to be evaluated in-person at WCIMA's newly established cough, cold, or fever clinic, or if they needed to go to the emergency room. Another goal was to provide counseling on management of symptoms, warning signs of clinical deterioration, and prevention of transmission. The goal of non-COVID-19 video visits was to approximate traditional, in-person care.

Although physical examinations were limited by the video visit format, providers were able to assess a patient's general appearance, respiratory effort, and affect. When indicated, providers could visually examine patients' skin, sclera/conjunctiva, and the oropharynx. A limited neurological

examination could also be performed. Heart rate and respiratory rate could be measured by the patient with provider guidance. For patients with home blood pressure monitors or pulse oximeters, additional vital signs could be collected.

Depending on the visit type, providers chose to document the visit using the COVID-19 assessment template or the usual primary care assessment template.

Quantitative Data Collection

We used a modified version of the RE-AIM Framework to describe the implementation of video visits at WCIMA during the COVID-19 pandemic (12). As such, we evaluated the Reach, Effectiveness, Adoption, and Implementation of the video visit initiative. We plan to collect data on Maintenance in the future. De-identified, practice-level data were generated from our electronic medical record and billing data.

To assess Reach, we obtained data on the number of completed video visits over time during the study period, demographics (age, gender, race, ethnicity, insurance type, relationship to practice) of the patients seen via video, the level of service of these video visits, and the most frequent diagnoses for which these video visits were billed.

To assess Effectiveness, we collected data on the proportion of scheduled visits that were: completed (as above), failed (due to technical difficulties), canceled, or no-shows. During the study period, but separate from our work, the Weill Cornell Physician Organization conducted a satisfaction survey via email among patients who completed video visits within the Department of Medicine. From this survey we obtained aggregate responses from patients for video visits conducted by WCIMA providers. The survey asked patients to: (1) rate their video visit experience (5-point Likert scale; one worst, five best); (2) report if they were satisfied with the care they received, compared with in-person visits (yes/no); (3) report what percent of care they would like to have as video visits in the future, compared to in-person (fill in %); and, (4) report if technical challenges occurred during the video visit (yes/no).

To assess Adoption, we collected data on the number of staff who assisted with video visit scheduling and the number and types of providers conducting video visits (attending vs. resident vs. nurse practitioners).

To assess Implementation, we collected data on the frequency with which the COVID-19 template was used and the number of iPads our clinic purchased to conduct video visits.

Because this study used de-identified, practice-level data, it was deemed exempt by the Weill Cornell Medicine Institutional Review Board. As such, written informed consent was not required for participation in this study.

Data Analysis

We present absolute counts and percent frequency of occurrence. We used the Kruskal-Wallis test to evaluate differences between median age categories, and the chi-square test to compare proportions. Analyses were conducted using the software package R (version 3.4.1, Vienna, Austria).

RESULTS

In the 4 weeks prior to the study period, 12 video visits were completed at WCIMA, with 6 (50%) occurring 1 day before our study period. During the 5-weeks study period, we completed a total of 1,030 video visits. The number of these visits by week is shown in **Figure 2**. In week 1, 113 video visits were completed, followed by 261 in week 2, 228 in week 3, 249 in week 4, and 176 in week 5.

Reach

Of the 1,030 completed video visits, 817 unique patients participated. Of these, 675 patients (82.6%) had 1 video visit each whereas 142 (17.4%) had >1 video visit (range: 2–9.) The demographics of patients with completed video visits are shown in **Table 1**. They had a median age of 50 years (Interquartile range: 40.6–61.3), 69% were women, nearly 25% were African American, 23% were Hispanic, 49% had commercial insurance, 28% had Medicaid, and 13% had Medicare. Compared to patients who completed in-person visits in our practice during July 1, 2019 to February 29, 2020 (our fiscal year-to-date data prior to the study period), those who completed video visits were younger (median age of 41–50 vs. 61–70 years [$p < 0.0001$]). The video visit group included more women (69 vs. 65%, $p = 0.004$), more Non-Hispanics (61 vs. 51%, $p < 0.0001$), more Whites (39 vs. 35%, $p = 0.008$), more commercially insured patients (49 vs. 36%, $p < 0.0001$) and fewer Medicare patients (13 vs. 32%, $p < 0.0001$) than our baseline population. Approximately one-fourth (28%) of the video visit group were insured by Medicaid, similar to our baseline population, of which 31% are insured by Medicaid ($p = 0.158$).

Effectiveness

During the study period, 1,475 video visits were scheduled, of which 1,030 (69.8%) were completed and 30 (2.0%) failed due to technical problems and were converted to telephone visits. A total of 19.1% of scheduled video visits no-showed and 9.1% were canceled either by the patient or provider.

Satisfaction data was obtained for 113 (13.8%) of the 817 patients who completed 1 video visit. Patients reported high satisfaction with their video visit (mean score of 4.6 on a 5-point scale [*SD*: 0.97]) and the vast majority (94.5%) of patients were satisfied with the level of care they received during their video visit compared with prior in-person visits (**Table 2**). Overall, patients preferred that 49% (*SD* 0.26) of future encounters with their provider be video visits instead of in-person visits. A total of 13.3% reported technical challenges during the video visit.

Adoption and Implementation

Overall, 70 providers (23 attendings, 38 residents, and nine nurse practitioners) conducted these 1,030 video visits and 22 staff members helped orient and schedule patients to video visits (**Table 3**). Among the video visits completed, the majority (92%) were associated with level 3 and four billing codes, indicating moderate complexity. Review of ICD-10 codes associated with primary billing diagnoses revealed that 428 encounters (42%) were potentially covid-19 related with diagnoses including:

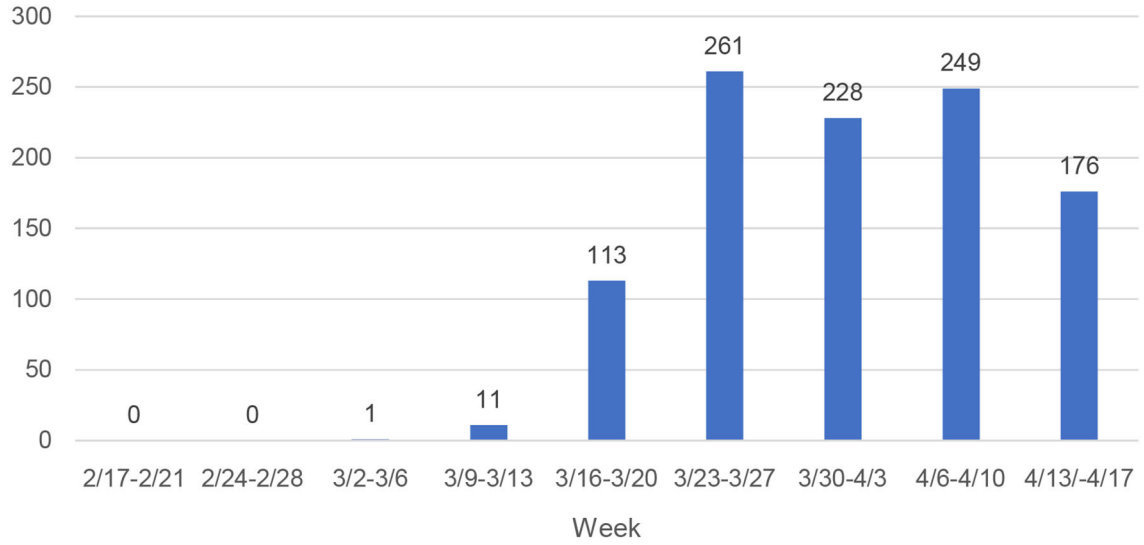


FIGURE 2 | Number of completed video visits by week pre-COVID-19 and during COVID-19. Video Visit Program began during week of 3/16-3/20 in response to the COVID-19 pandemic.

TABLE 1 | Demographic characteristics of patients who completed video visits during the study period compared to patients who completed in-person visits during the prior fiscal year.

Characteristics	Completed video visits during study period (n = 1,030)	Completed in-person visits prior to study period (N = 38,614)	Omnibus p-values*	Bonferroni adjusted p-values for multiple comparisons
Age, median category, y.	41–50**	61–70	<0.0001	
Sex				
Male	30.8%	35.2%	0.0035	
Female	69.2%	64.8%		
Race				
Black	24.7%	22.0%	0.00003	0.156
Asian / Pacific Isl.	7.9%	8.0%		0.990
White	39.1%	34.5%		0.008
Other/unknown	28.1%	35.2%		<0.00001
Ethnicity				
Hispanic	22.9%	19.8%	<0.00001	0.042
Non-Hispanic	61.0%	50.5%		<0.00001
Other/unknown	16.1%	29.7%		<0.00001
Insurance				
Medicare	13.0%	31.5%	<0.00001	<0.00001
Medicaid	27.6%	30.6%		0.158
Commercial	49.0%	36.5%		<0.00001
Self-pay/other	10.4%	1.4%		<0.00001
Relationship to Practice				
New patient	2.3%	9.3%	<0.00001	
Established patient	97.7%	90.7%		

**Two-tailed chi-square test.*
***Median age for adults who completed video visit was 50.0 years (Interquartile range: 40.6–61.3).*

TABLE 2 | Patient satisfaction and attitudes toward video visits.

Survey domain	Response (n = 113)* (mean [*SD*]) or %
Overall experience with video visit (one worst, five best)	4.6 (0.97)
Satisfied with the level of care offered during video visit, compared with in-person visit?	94.5%
Percent of future care preferred as video visit vs. in-person	49% (0.26)
Experienced technical challenges during video visit	13.3%

**13.8% survey response rate.*

TABLE 3 | Description of providers, level of service, and template usage for completed video visits.

Characteristics	Video visits during COVID (n = 1,030)
Provider rendering video visit	
Attending (MD)	69.1%
Nurse Practitioner	8.5%
Resident	22.3%
Level of service of visit*	
99202/99212	1.9%
99203/99213	44.5%
99204/99214	47.7%
99205/99215	2.3%
Other**	3.4%
COVID-19 structured template used	22.9%

**Level of service of visit: These CPT codes for ambulatory visits denote whether the patient is new or established and the complexity of medical decision making.*
***Other includes visits for preventative health, smoking cessation, anticoagulation counseling and psychiatric illness. "Failed" video visits (N = 30), which were converted to telephone only, were not counted in denominator.*

cough, upper respiratory infection, fever, chills, shortness of breath, anosmia, wheezing, pneumonia, asthma, musculoskeletal pain, and COVID-19. Overall, 22.9% of video visits used the COVID-19 template. A total of 17 iPads were purchased during the study period.

DISCUSSION

This study describes the implementation of a video visit program at a large academic hospital-based primary care practice in New York City during the COVID-19 pandemic. Overall, 70 providers completed a total of 1,030 video visits over a 5-weeks period, compared to 12 video visits completed in the preceding 4 weeks. Video visits increased greatly during weeks 1 and 2, plateaued in weeks 3 and 4, and dropped off in week 5, which may reflect the overall trend of health care utilization for COVID-19 in New York City during this time (17). Video visits occur more often among younger adults, women, and those with commercial insurance, compared to those with in-person visits pre-COVID. Although we were only able to obtain satisfaction data on a subset of patients, the majority reported high satisfaction with their video visit experience.

Another key finding was that despite our quick ramp-up period, issues with the technology itself among those with scheduled visits appeared to be modest. For example, only 2% of initiated video visits were not completed and converted to telephone encounters. Additionally, only 13% of patients reported challenges with technology during their video visit encounter. Although we could not assess the number of patients who did not engage with video visits, our findings suggest that video visits may be more feasible than previously thought. That is, prior studies have found patients were uncomfortable with the technology and had technical issues during video visits (18, 19). We hypothesize that during COVID-19, patients and providers may have been more willing to engage with and troubleshoot technological challenges in order to be seen. Of note, during the study period, our video visit no-show rate was 19%, which is similar to our in-person no-show rate of 20%. All told, these data signal that in the context of social distancing, and with appropriate workflow and administrative processes, implementation of video visit technology is feasible in primary care.

To our knowledge, this is one of the first studies to describe the implementation of video visits during COVID-19 in the primary care setting. There have been studies describing the implementation of video visits pre-COVID-19 across a range of clinical specialties (20) as well as three studies describing the implementation of video visits during COVID-19, one among an inpatient urology consultation service (21), one among an obstetrics practice (22), and another in urgent care (23). A recent NEJM Catalyst article (3) qualitatively described the experiences of four primary care practices who have gone "virtual" since COVID-19. Like us, they report low utilization of video visits pre-COVID and high utilization during COVID-19. Our study adds to this body of literature by offering a detailed description of video visit implementation, including a Video Visit Handbook, as well as data on reach, effectiveness, and adoption.

Our findings not only have implications for clinical care and healthcare delivery during COVID-19, but also raise questions about the utilization of video visits in primary care moving forward. First, although we lack data on our entire sample, satisfaction scores for video visits were high and patients preferred to have half of their future visits occur via video, compared to in-person. Future research will need to determine if this preference persists after social distancing policies are relaxed. Additionally, studies are needed to assess providers' perceptions regarding the clinical effectiveness of video visits for COVID and non-COVID symptoms. Second, although video visits minimized transmission risk, they also limited the ability of providers to perform a complete physical examination and measure vital signs. Some practices, including ours, have incorporated aspects of remote monitoring into video visit encounters (24). Moving forward, key questions include: *How to best deploy this equipment to patients? Which patients benefit from monitoring? How can these data be captured electronically? Will the cost of such devices will be reimbursable* (25, 26). Third, attention to who is not utilizing video visits will be important to avoid exacerbating existing inequities in health and healthcare. We found that older adults and Medicare beneficiaries were less likely to engage, which may be due to difficulties with technology, lower levels

of internet use, sensory impairments, or lack of confidence with technology (10, 11, 27). It is also likely those with limited English proficiency and health literacy, as well as structurally disadvantaged populations, may lack the ability and/or resources to access technology (28). Understanding these barriers will be critical for more equitable implementation. Fourth, primary care physicians may need to create new processes and pathways with specialty providers to co-manage COVID-19 patients who have persistent or multi-organ complications (29, 30). Finally, as CMS and other payers broaden their telehealth payment policies during COVID-19, the economic impact of expanding video visit use will need to be monitored.

Limitations

Patient satisfaction data was only available from some patients who utilized video visits, which may introduce response bias. Additionally, we do not yet have outcome data on patients with completed video visits. Finally, this study did not include the perspectives of providers and staff on implementing video visits.

CONCLUSION

At the height of the COVID-19 pandemic in New York City, we implemented a video visit program at our primary care practice to evaluate and treat patients for their symptoms while maintaining social distance. During a 5-weeks period, 70 providers completed 1,030 video visits, compared to only 12 video visits completed in the preceding 4 weeks. New workflows for staff, providers, and patients were developed to implement this program. Overall, patients reported high satisfaction with the care they received during their video visits. Our findings suggest that video visits provide a feasible way to care for patients with and without COVID-19 symptoms. Additional study on the sustained implementation of video visits in primary care, as well as their effect on patient outcomes, is warranted.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval of our study was granted through the Weill Cornell Institutional Review Board. Because our study used de-identified, practice-level data, it was deemed exempt from full board review based on federal regulations. As such, written informed consent was not required for participation in this study.

AUTHOR CONTRIBUTIONS

SS, LK, LG, and MS were involved in the study design and methods. ER, MS, and SS were involved in the data analysis. All authors contributed sufficiently to the writing and editing of this article.

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SUPPLEMENTARY MATERIAL

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REFERENCES

1. CDC. *Cases, Data, and Surveillance*. CDC. (2020). Available online at: https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/index.html (accessed May 6, 2020).
2. ACP. *Internists emphasize Importance of Assessing In-Office Visits and Transitioning to Virtual Visits During COVID-19 Emergency*. ACP newsroom. ACP. (2020). Available online at: https://www.acponline.org/acp-newsroom/internists-emphasize-importance-of-assessing-in-office-visits-and-transitioning-to-virtual-visits (accessed May 14, 2020).
3. Ateev M, Kristin R, Brockmeyer DM, Barnett ML, Bender JA. Rapidly converting to "virtual practices": outpatient care in the era of Covid-19. *Innov Care Delivery*. (2020) 1. doi: 10.1056/CAT.20.0091
4. Levine DM, Dixon RF, Linder JA. Association of structured virtual visits for hypertension follow-up in primary care with blood pressure control and use of clinical services. *J Gen Intern Med*. (2018) 33:1862–7. doi: 10.1007/s11606-018-4375-0
5. Barnett ML, Ray KN, Souza J, Mehrotra A. Trends in telemedicine use in a large commercially insured population, 2005-2017. *JAMA*. (2018) 320:2147–9. doi: 10.1001/jama.2018.12354
6. Dorsey ER, Topol EJ. State of telehealth. *N Engl J Med*. (2016) 375:154–61. doi: 10.1056/NEJMra1601705
7. Tepper D, Weissman M. Can we live-stream primary care? Challenges in the adoption of econsults and video visits. In: *SGIM Forum*. Vol. 43 (2020). Available online at: https://www.sgim.org/File%20Library/SGIM/Resource%20Library/Forum/2020/SGIM-FEB-1.pdf
8. *Telehealth Index: 2019 Consumer Survey*. (2020). Available online at: https://business.amwell.com/resources/telehealth-index-2019-consumer-survey/
9. Ranganathan C, Balaji S. Key factors affecting the adoption of telemedicine by ambulatory clinics: insights from a statewide survey. *Telemed J E Health*. (2020) 26:218–25. doi: 10.1089/tmj.2018.0114

10. Pew Research Center. *Americans Internet Access: Percent of Adults 2000–2015.* Pew Research Center. (2020). Available online at: https://www.pewresearch.org/internet/2015/06/26/americans-internet-access-2000-2015/ (accessed May 7, 2020).
11. Digital Divides. *Pew Research Center.* (2015) Available online at: https://www.pewresearch.org/internet/2015/09/22/digital-divides-2015/ (accessed May 7, 2020).
12. Glasgow RE, Vogt TM, Boles SM. Evaluating the public health impact of health promotion interventions: the RE-AIM framework. *Am J Public Health.* (1999) 89:1322–7. doi: 10.2105/AJPH.89.9.1322
13. Sholle ET, Pinheiro LC, Adekkanattu P, Davila MA, Johnson SB, Pathak J, et al. Underserved populations with missing race ethnicity data differ significantly from those with structured race/ethnicity documentation. *J Am Med Inform Assoc.* (2019) 26:722–9. doi: 10.1093/jamia/ocz040
14. Clinical Directors Network, Inc. *An Overview of Hybrid Effectiveness-Implementation Designs.* (2020). Available online at: https://www.cdnetwork.org/library/an-overview-of-hybrid-effectiveness-implementation-designs (accessed Jul 22, 2020).
15. Curran GM, Bauer M, Mittman B, Pyne JM, Stetler C. Effectiveness-implementation hybrid designs: combining elements of clinical effectiveness and implementation research to enhance public health impact. *Med Care.* (2012) 50:217–26. doi: 10.1097/MLR.0b013e3182408812
16. Emergencies C. *CMS Letter to Clinicians to Summarize Actions CMS Has Taken to Ensure Clinicians Have Maximum Flexibility to Reduce Unnecessary Barriers to Providing Patient Care.* (2020). Available online at: https://www.cms.gov/files/document/covid-dear-clinician-letter.pdf (accessed May 2, 2020).
17. www.reuters.com. *New York Hospitalizations Fall for First Time in Coronavirus Pandemic: Governor – Reuters.* (2020). Available online at: https://www.reuters.com/article/us-health-coronavirus-usa-new-york/new-york-hospitalizations-fall-for-first-time-in-coronavirus-pandemic-governor-idUSKCN21W2DH (accessed May 15, 2020).
18. Hanson RE, Truesdell M, Stebbins GT, Weathers AL, Goetz CG. Telemedicine vs office visits in a movement disorders clinic: comparative satisfaction of physicians and patients. *Mov Disord Clin Pract.* (2019) 6:65–9. doi: 10.1002/mdc3.12703
19. Viers BR, Lightner DJ, Rivera ME, Tollefson MK, Boorjian SA, Karnes RJ, et al. Efficiency, satisfaction, and costs for remote video visits following radical prostatectomy: a randomized controlled trial. *Eur Urol.* (2015) 68:729–35. doi: 10.1016/j.eururo.2015.04.002
20. Powell RE, Stone D, Hollander JE. Patient and health system experience with implementation of an enterprise-wide telehealth scheduled video visit program: mixed-methods study. *JMIR Med Inform.* (2018) 6:e10. doi: 10.2196/medinform.8479
21. Gadzinski AJ, Andino JJ, Odisho AY, Watts KL, Gore JL, Ellimoottil C. Telemedicine and eConsults for hospitalized patients during COVID-19. *Urology.* (2020) 141:12–4. doi: 10.1016/j.urology.2020.04.061
22. Spiegelman J, Krenitsky N, Syeda S, Sutton D, Moroz L. Rapid development and implementation of a Covid-19 telehealth clinic for obstetric patients | catalyst non-issue content. *NEJM Catal Innov Care Delivery.* (2020). doi: 10.1056/CAT.20.0170
23. Mann DM, Chen J, Chunara R, Testa PA, Nov O. COVID-19 transforms health care through telemedicine: evidence from the field. *J Am Med Inform Assoc.* (2020) 27:1132–5. doi: 10.1093/jamia/ocaa072
24. Volpp KG, Diamond SM, Shrank WH. Innovation in home care: time for a new payment model. *JAMA.* (2020) 36:83–90. doi: 10.1001/jama.2020.1036
25. FDA. *Enforcement Policy for Non-Invasive Remote Monitoring Devices Used to Support Patient Monitoring During the Coronavirus Disease-2019 (COVID-19) Public Health Emergency.* FDA. (2020). Available online at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/enforcement-policy-non-invasive-remote-monitoring-devices-used-support-patient-monitoring-during (accessed May 18, 2020).
26. www.3mhisinsideangle.com. *Remote Patient Monitoring in the Time of COVID-19–3M Inside Angle.* (2020). Available online at: https://www.3mhisinsideangle.com/blog-post/remote-patient-monitoring-in-the-time-of-covid-19/ (accessed May 18, 2020).
27. Cimperman M, Brenčič MM, Trkman P, Stanonik M de L. Older adults' perceptions of home telehealth services. *Telemed J E Health.* (2013) 19:786–90. doi: 10.1089/tmj.2012.0272
28. Nouri S, Khoong EC, Lyles CR, Karliner L. Addressing equity in telemedicine for chronic disease management during the Covid-19 pandemic | catalyst non-issue content. *NEJM Catal Innov Care Delivery.* (2020). doi: 10.1056/CAT.20.0123
29. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (covid-19) settings: recommendations from the REPROGRAM consortium. *Front Cardiovasc Med.* (2020) 7:112. doi: 10.3389/fcvm.2020.00112
30. Bhaskar S, Sharma D, Walker AH, McDonald M, Huasen B, Haridas A, et al. Acute neurological care in the COVID-19 era: the pandemic health system resilience PROGRAM (REPROGRAM) consortium pathway. *Front Neurol.* (2020) 11:579. doi: 10.3389/fneur.2020.00579

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Telemedicine Across the Globe-Position Paper From the COVID-19 Pandemic Health System Resilience PROGRAM (REPROGRAM) International Consortium (Part 1)

Sonu Bhaskar[1,2,3]*, *Sian Bradley*[1,4], *Vijay Kumar Chattu*[1,5], *Anil Adisesh*[1,5], *Alma Nurtazina*[1,6], *Saltanat Kyrykbayeva*[1,6], *Sateesh Sakhamuri*[1,7], *Sanni Yaya*[1,8], *Thankam Sunil*[1,9], *Pravin Thomas*[1,10], *Viviana Mucci*[1,11], *Sebastian Moguilner*[1,12], *Simon Israel-Korn*[1,13], *Jason Alacapa*[1,14], *Abha Mishra*[1,15], *Shawna Pandya*[1,16], *Starr Schroeder*[1,17], *Ashish Atreja*[1,18], *Maciej Banach*[1,19,20] and *Daniel Ray*[1,21]

[1] Pandemic Health System REsilience PROGRAM (REPROGRAM) Consortium, REPROGRAM Telemedicine Sub-committee, Sydney, NSW, Australia, [2] Department of Neurology, Liverpool Hospital and South Western Sydney Local Health District, Sydney, NSW, Australia, [3] Neurovascular Imaging Laboratory & NSW Brain Clot Bank, Ingham Institute for Applied Medical Research, The University of New South Wales, UNSW Medicine, Sydney, NSW, Australia, [4] The University of New South Wales (UNSW) Medicine Sydney, South West Sydney Clinical School, Sydney, NSW, Australia, [5] Department of Medicine, University of Toronto, St. Michael's Hospital, Toronto, ON, Canada, [6] Department of Epidemiology and Biostatistics, Semey Medical University, Semey, Kazakhstan, [7] The University of the West Indies, St. Augustine, Trinidad and Tobago, [8] School of International Development and Global Studies, University of Ottawa, Ottawa, ON, Canada, [9] Department of Public Health, University of Tennessee, Knoxville, Knoxville, TN, United States, [10] Department of Neurology, University Hospitals Birmingham NHS Foundation Trust, Birmingham, United Kingdom, [11] School of Science, Western Sydney University, Sydney, NSW, Australia, [12] Global Brain Health Institute, Trinity College Dublin, Dublin, Ireland, [13] Movement Disorders Institute, Department of Neurology, Sheba Medical Center, Tel Hashomer, Ramat Gan & Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel, [14] metaHealth Insights and Innovation, Manila, Philippines, [15] Department of Anthropology, University of Delhi, New Delhi, India, [16] University of Alberta, Alberta Health Services and Project PoSSUM, Edmonton, AB, Canada, [17] Penn Medicine Lancaster General Hospital and Project PoSSUM, Lancaster, PA, United States, [18] Icahn School of Medicine, Mount Sinai Hospital, Mount Sinai, New York, NY, United States, [19] Polish Mother's Memorial Hospital Research Institute (PMMHRI) in Lodz, Cardiovascular Research Centre, University of Zielona Gora, Zielona Gora, Poland, [20] Department of Hypertension, Medical University of Lodz, Lodz, Poland, [21] Farr Institute of Health Informatics, University College London (UCL) & NHS Foundation Trust, Birmingham, United Kingdom

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Edited by:
Alberto Eugenio Tozzi, Bambino Gesù Children Hospital (IRCCS), Italy

Reviewed by:
Caterina Rizzo, Bambino Gesù Children Hospital (IRCCS), Italy
Laszlo Balkanyi, University of Pannonia, Hungary

***Correspondence:**
Sonu Bhaskar
Sonu.Bhaskar@health.nsw.gov.au

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Coronavirus disease 2019 (COVID-19) has accelerated the adoption of telemedicine globally. The current consortium critically examines the telemedicine frameworks, identifies gaps in its implementation and investigates the changes in telemedicine framework/s during COVID-19 across the globe. Streamlining of global public health preparedness framework that is interoperable and allow for collaboration and sharing of resources, in which telemedicine is an integral part of the public health response during outbreaks such as COVID-19, should be pursued. With adequate reinforcement, telemedicine has the potential to act as the "safety-net" of our public health response to an outbreak. Our focus on telemedicine must shift to the developing and under-developing nations, which carry a disproportionate burden of vulnerable communities who are at risk due to COVID-19.

Keywords: telemedicine, telehealth, digital technologies, health policy, COVID-19, framework, recommendations (guidelines), geographics

INTRODUCTION

The novel coronavirus disease (COVID-19) emerged at the end of 2019 in Wuhan (People's Republic of China) and the viral outbreak was declared as a pandemic by World Health Organization (WHO) on March 11, 2020 (1). During the conception of this article, the pandemic is still spreading, and the fight is still ongoing. The World Health Organization (WHO) COVID-19 situation report, as of September 10, 2020, showed over 27.7 million confirmed cases and over 899,000 total deaths spread across continents (2). As we continue to grapple with the "sky-scraping" deaths around the world, the difficulties of ensuring the continuity of care and maintaining the capacity of health systems pose a continued threat (3–6). The global public health response to manage and contain the pandemic has placed a paramount emphasis on telemedicine toward remote delivery of care cutting across various medical sub-specialities (7). With the exponential growth in internet users, the availability and/or accessibility of already existing telemedicine services have been bolstered. In 2018, the global telemedicine market was valued at USD 38,046 million and is expected to rise to USD 103,897 million by 2024 (8). Variations in digital preparation/maturity of hospitals, availability, access, and implementation of telemedicine are experienced across the world (9).

Pandemics challenge the preparedness of health systems-exposing the structural barriers (10). Amidst global lockdown or quarantine measures imposed due to COVID-19, access to telehealth becomes increasingly crucial and efforts to rectify disparities are warranted (11). In particular, telemedicine has a vital role to play in low- and middle-income countries (LMICs) and remote areas by improving access to healthcare to under-resourced regions (12). This article seeks to analyse the status of implementation of telemedicine around the world, and factors that influence the uptake and implementation of telemedicine. We will also discuss progress and challenges in telemedicine faced by various geographics during the COVID-19 era.

METHODS

Existing telemedicine frameworks and policies of various countries/regions and their implementation stage are analyzed using Gladhart (13) and Pan American Health Organization (PAHO/WHO) hat (14) models. An evidence synthesis approach, to summarize pre-COVID-19 and current (during COVID-19) policy frameworks and changes due to COVID-19, was undertaken to develop expert recommendations for strengthening telemedicine across the globe. Using a case-based approach, the official ministry of health or government websites, media sources, and published literature were examined to critically analyse the telemedicine frameworks and COVID-19 specific response. For each country analyzed, following policy questions were examined: (a) Is there a national telemedicine framework before COVID-19?, (b) What stage that framework is in?, (c) What are the gaps in the telemedicine implementation?, (d) What telemedicine specific policy changes, if any, have been adopted in response to COVID-19? and (e) What could be done to potentially improve the telemedicine implementation in the future in the respective country/region? Based on specific challenges identified using the analyses across geographics, specific policy-based targeted recommendations poignant to telemedicine use, during the current COVID-19 pandemic and beyond, are made.

RESULTS

The existing telemedicine framework/s across various regions/countries, status or maturity of telemedicine implementation, and various developments or changes that have been adopted during the COVID-19 are summarized. A comparative analysis of existing telemedicine frameworks using Gladhart and WHO/PAHO hat models, their stage, and recommendations from this consortium on improving telemedicine uptake during and beyond COVID-19 have been provided in **Table 1**.

Status of Telemedicine Services in East, Southeast, and South Asia

A 2016 multi-country study by Suzuki et al. assessed the possibility of introducing telemedicine services in several developing Asian countries (15). Indicators including healthcare environment, national information technology (IT) progress and economic status were used to assess the viability of internet-based medical services. It was found that countries such as Thailand, which have a shortage of physicians, but high levels of internet and mobile phone penetration, have a high possibility of telemedicine implementation. Despite high gross domestic product (GDP), countries like India and China face substantial variations in telemedicine uptake between urban and rural areas. Rural-urban gaps need to be reduced to leverage nation-wide telemedicine effectively.

Asian telehealth platforms are reporting drastically increased usages, such as Indonesian telehealth platforms Alodokter, Halodoc, and GrabHealth, driven by government support and recommendation (16). The Doctor Anywhere COVID-19 Medical Advisory Clinic has also been rolled out across several Asian countries such as Singapore, Thailand, and Vietnam, in which members of the public can undergo a video consultation through the app if they suspect they might have COVID-19 (17). Screening questions about symptoms, travel history, and close contacts will help determine if the person should admit themselves to the hospital. However, the level of subsequent support and payables differ between countries, with Singapore leading the way in ambulance-linkage and free consultation. Collaboration across Asian regions is needed, as well as bridging any access gaps within countries.

Singapore

Singapore is a front-runner in Asia in terms of telemedicine adoption and healthcare system efficiency. In 2018, the Singapore Ministry of Health launched a regulatory sandbox to facilitate innovation and form relationships between the government and telehealth partners (18). In April 2019, the Health Science

TABLE 1 | Status of telemedicine in different geographical regions and recommendations from the Consortium.

Region	Pre-COVID-2019 status of telemedicine		Current status of telemedicine		Recommendations from Consortium
	Gladhart Model	**PAHO Hat Model**	**Gladhart Model**	**PAHO Hat Model**	
Central Asia	Central Asian countries could follow the example set by Kazakhstanis in the adoption stage of telemedicine, in the process of implementing *Digital Kazakhstan* state program.	Kazakhstan has strategized programs to account for its large geographical stage, has formulated public policy, and is in the development phase of rolling out programs.	Kazakhstan was able to respond to the COVID-19 crisis through the adaptation of telemedicine and the establishment of telehealth headquarters.	Kazakhstan optimized telemedicine strategies with the backing of government support to provide primary and specialist care.	Countries with low population density could use Kazakhstan's focus on telemedicine as an example of how to provide far-reaching care. Nation-wide hospital networks and government support of telehealth startups could further telemedicine development.
China	China has varied degrees of implementation across telehealth realms. It demonstrates invention in novel technologies and population health management; however, some telemedicine regulations and implementation are still entry-level and requires further clarification.	China has begun to organize and develop telehealth networks, particularly in major cities such as Shanghai. However, due to large economic disparities between rural and urban areas, a further strategy is needed to avoid disparities in access to care.	COVID-19 has seen continued invention in China, with innovations such as the Wuhan AI hospital. Telehealth companies are also seeing increased adoption.	The Chinese government has taken a serious approach to COVID-19 management and continues to consider public policy and strategization in affected Chinese regions.	Clear regulatory telehealth frameworks would help facilitate the wide-scale application of telemedicine services. Collaboration between Asian regions is also needed to spread technological innovations.
Singapore	Singapore is encouraging invention through its regulatory sandbox, in terms of direct-to-patient telehealth platforms. Its National Framework has also allowed for adaptation from different hospitals and developers.	Singapore has fostered relationships between government, commercial developers, hospitals, and institutions to implement and optimize telemedicine strategies.	Relaxation of some regulations has allowed for the adaptation of telemedicine services by primary and specialist physicians. Continued invention and integration of telehealth apps and services have also seen improved patient care.	The continued development of regulatory support and integration of telehealth start-ups into the health system has demonstrated effective COVID-19 management solutions.	In a population-dense country such as Singapore, efforts to distance patients are paramount. With COVID-19 cases on the downturn, the focus should remain on encouraging innovation and consideration of international strategies such as mobile stroke units and artificial intelligence systems for Singapore.
Bangladesh	Bangladesh is in the entry stage of telemedicine progress, with no national telemedicine framework and lack of infrastructure.	Bangladesh hospitals do have telemedicine systems in place, with the utilization of multiple hubs and spoke structures taking place. Public policy planning is needed before further optimization can take place.	Limited analysis of telehealth implementation as a result of COVID-19 in Bangladesh is available.		The system will benefit from gaps analyses to ensure various aspects of telemedicine from infrastructure to privacy are adequately addressed
India	India is in the adoption stage of telemedicine, with governance bodies and guidelines in place, indicating the willingness of the government to implement telemedicine programs. However, ongoing issues such as limited infrastructure and lack of comprehensive regulation inhibit this process.	India needs to further establish a public policy to progress to the widespread development of telemedicine. Issues that require targeting include lack of clear policy, comprehensive guidelines, formats, or accountability frameworks.	Due to COVID-19, more patients have turned to telemedicine and hence pushed the adoption of telemedicine in more healthcare practices.	The Indian government issued new guidelines for telemedicine practice in March 2020. This step-in public policy aims to give further guidance to the practice of telemedicine in India.	To achieve widespread telemedicine in India, infrastructural and access issues must first be targeted. Furthermore, it must be ensured that comprehensive and binding legislation exists that provides clear physician-patient formats to cover issues of consent, privacy, and utilization.

(Continued)

TABLE 1 | Continued

Region	Pre-COVID-2019 status of telemedicine		Current status of telemedicine		Recommendations from Consortium
	Gladhart Model	**PAHO Hat Model**	**Gladhart Model**	**PAHO Hat Model**	
Africa	The state of telehealth progress in Africa varies country-to-country. Countries with more advanced infrastructure and economic development, such as South Africa, are in the adoption and adaptation stages, whilst other LMIC is in the entry stage and require international support.	Broadly, strategic consideration of cultural, economic, and infrastructural needs is required to form a foundation for telehealth development in many African regions. Solutions to internet access and economic inequalities are needed for effective program development.	As COVID-19 cases begin to rise in Africa, support from other countries and the WHO is needed to assist with entry of the telemedicine support.	Public policy changes in countries such as South Africa reflect the need for expanded telemedicine capabilities during this time. Increased strategization is needed for countries with limited access to current telehealth.	Different regions of Africa require unique approaches, with some effective telehealth programs already in place. Infrastructure and government support of telemedicine partnerships are required to set the groundwork in many countries. International funding is required before local government funding will be sufficient.
Latin America	The level of telehealth in Latin America is mixed, with some examples of the invention, such as innovative telehealth partnerships. Increased adoption is needed across the population through the promotion of such platforms.	Many countries have a National Telehealth Strategy; however, national telehealth departments and clear regulations are required. Further public policy and development of telehealth infrastructure would be beneficial.	Increased adoption of telemedicine as a result of COVID-19 has been seen in some Latin American countries.	Public policy and promotion of telehealth platforms have been seen, but further work could be done on a governmental level to increase popularity.	Implementing change management strategies with the support of various stakeholders is required in this region. The penetration of commercial telemedicine solutions could also give more options to patients.
Caribbean	Many Caribbean countries are still in the entry phase of telemedicine.	Some telemedicine networks exist, and increasing levels of telehealth programs such as national EHR systems are eventuating. Identification of needs is needed for strategy, as are coordination teams for the organization.	Limited analysis of telehealth implementation as a result of COVID-19 in the Caribbean is available.		Basic telehealth programs are required in Caribbean countries. International models of technologies such as EHR systems may be a building block in this direction. Region-wide telehealth solutions through collaboration could also be advantageous.
Australia	Australia is in the invention stage of telemedicine progress. It needs to be ensured that these benefits extend to remote Australia, due to its vast land size and relatively isolated communities	Australia continues to seek to optimize and evaluate current telemedicine initiatives. Ongoing public policy relevant to disadvantaged communities and those with limited mobility/access is required.	Adaptation of current telehealth platforms is ongoing, and expansion to specialist care is recommended.	Governmental regulation changes have allowed for increased access to telehealth, through a comprehensive Medicare public health insurance Scheme.	Focus on specialist care delivery is required. Furthermore, collaboration with international think tanks and healthcare bodies is required for continual innovation in telemedicine delivery across the healthcare system.
New Zealand	New Zealand is in the invention stage of telemedicine progress, and further support of the technological sector is needed to bring it to the level of the likes of Australia and the USA.	New Zealand's Ministry of Health and dedicated National Telehealth Service allows for targeted telemedicine strategy.	The adoption of telemedicine has been promoted by clarifying guidelines and advice to healthcare practitioners.	Continued consideration of best practices and public policy surrounding telehealth is ongoing in New Zealand.	Support for innovation and international collaboration would be beneficial for New Zealand.
Canada	Canada could be considered as being in both the appropriation and invention stage of telemedicine progress, with levels of technological innovation combined with provincial differences in uptake.	Policy surrounding telemedicine and billing differs according to provinces. Government support of telehealth initiatives promises continued development.	Physician colleges and government guidelines seek to provide clarity and increase adoption during this time.	The COVID-19 pandemic has pushed the need for telemedicine development in Canada and highlighted the need to support urban regions as well as rural areas.	National cohesiveness across provinces and government promotion of the telehealth industry is useful.

(Continued)

TABLE 1 | Continued

Region	Pre-COVID-2019 status of telemedicine		Current status of telemedicine		Recommendations from Consortium
	Gladhart Model	**PAHO Hat Model**	**Gladhart Model**	**PAHO Hat Model**	
USA	The USA is a frontrunner in telemedicine invention through hospital and technological innovations.	The USA continues to implement and optimize telehealth programs within and across states.	Government support and regulatory relaxations allow for increased penetrance of telemedicine across specialities.	COVID-19 has pushed the need for innovation within the telemedicine sector, and continued monetary support and funds allocation will help to continue this trajectory.	Disparities in health care insurance within the USA result in different levels of access for patients. It needs to be ensured that those patients who are immunocompromised, disadvantaged, immobile, and suffering from chronic care are receiving appropriate levels of support. American social platforms that are being utilized for teleconference means also need to ensure the privacy and security of their users.
UK	The UK is in the invention stage of telemedicine and continues to innovate with support from large telecommunication companies.	The UK continues to implement and optimize telemedicine services and has a governmental "Long Term Plan" in place.	Primary care, clinical trials, counseling, and chronic disease reviews are all rapidly being moved to telehealth delivery as different specialities increasingly adopt telemedicine.	Telehealth platforms continue to see increasing development and utilization as pressure from the COVID-19 pandemic pushes the need for remote services.	Ongoing governmental support of telemedicine innovation is necessary, and sharing of technological resources with other successful European healthcare systems such as France and Germany would be favorable.
Italy	Italy has mixed progress in telemedicine, with some areas being entry-level and others at adoption and adaptation. This is due to some deficiencies in the hospital infrastructure, supply-chain issues, and internet capabilities.	Italy requires public policy support of telemedicine, as it is not considered an essential item to patients within its National Health Service.	Italian hospitals became overwhelmed during the COVID-19 crisis. Hospitals and regions that were effectively available to adapt to telemedicine need to share their experiences.	Italian health care practitioners are sharing their experiences to identify needs and demonstrate the urgent need for telemedicine solutions.	This pandemic experience demonstrates the devastating impact of sudden surges in medical resources and personnel demand can have in the wake of unexpected disasters. Public policy support of telemedicine is needed in Italy, with successful hospitals sharing knowledge at a national level.
Spain	Spain is in both the entry and adoption stage of telemedicine, with progress varying in region to region.	Spain lacks a national telemedicine policy, which is required for the development of nation-wide effective telemedicine strategies.	Some hospitals have reported a rapid switch to telemedicine for outpatients and staff conferences by adapting current telemedicine technologies. Spain has also seen increased adoption of telehealth app usage.	There haven't been any notable policy changes to telemedicine in Spain as a result of the COVID-19 crisis. As with Italy, successful hospitals and regions need to share their successful strategies.	Precise governmental regulation and legislation that directly targets telemedicine are required in Spain. Furthermore, cooperation with other European countries would help to implement telemedicine models.

Authority released regulatory guidelines to clarify existing regulations around telemedicine and telehealth in Singapore, including categorization and risk stratification of services and regulatory controls surrounding medical devices (19). There are now 11 start-ups in the sandbox, with platforms such as MyDoc and DoctorAnywhere experiencing major upturns in use during COVID-19 (20). In April 2020, the Ministry of Health also announced that patients who qualify for Community Health Assist Scheme and MediSave, with a listed chronic disease, can now be covered to see their regular physicians through teleconference. However, this does not apply to new patients that have not yet had a physical consultation (21). In the context of COVID-19, Singapore Medical Association has issued specific guidelines and advice on the use of telemedicine during an infectious disease outbreak (22).

India

Before 2020, telemedicine in India was governed by the IT Act, 2000, with gaps in clarity on privacy, security, and patient confidentiality, putting both patients and clinicians at risk (23). The Indian government issued new guidelines for telemedicine practice in March 2020 (24). Previously, a National Telemedicine Task Force was set up by the Ministry of Health (MOH) in 2005. A policy action toward digitizing healthcare was initiated by the Ministry of Health and Family Welfare of India (MoHFW) following the launch of the "Digital India" campaign by the Government of India in 2015. Later, in 2017, the National Health Policy (NHP) set forth goals to create an integrated health information system for all stakeholders in the health system, to improve efficiency, transparency, and citizen experience (25). The National Digital Health Blueprint (NDHB), released in January 2020, presents a detailed architectural framework of a "*Federated National Health Information System.*" It proposes to link systems within private- and public-health provider organizations across primary-, secondary-, and tertiary-care value chains (26). Another initiative by MoHFW is the start and delivery of online OPD services for all Indian citizens through the National Teleconsultation Service (eSanjeevaniOPD) (27). The eSanjeevani OPD- "Stay home OPD" will potentially improve accessibility and enable citizens to avail free health services through teleconsultations (27). More recently, on 15th August 2020, on the occasion of the 74th Indian Independence Day celebrations, the Prime Minister of India, Mr. Narendra Modi, officially launched the "National Digital Health Mission," under the aegis of which every Indian citizen will be given a "Digital Health Card" containing all the information on their health issues, diagnosis, and relevant reports (28).

Telemedicine projects have been pursued by the Indian Space Research Organization (ISRO), Department of Information Technology, Ministry of External Affairs and MoHFW (29). However, these programs have been limited in their implementation and efficacy, barring few corporate hospitals that have developed and implemented their telemedicine networks (29). Despite the importance of telemedicine laid out in Digital India and NHP, telemedicine in India warrants a comprehensive strategy toward rapid implementation and scale-up. For example, the Telemedicine Pilot Project initiated by the ISRO has shown snail progress and uptake, connecting only 45 remote and rural hospitals and 15 super-speciality hospitals in 20 years (30). This has been attributed to limited infrastructure and lack of regulation (31).

Some of the national projects undertaken by the Ministry of Health and Family welfare are Integrated Disease Surveillance Project (IDSP), National Cancer Network (ONCONET), National Rural Telemedicine Network, National Medical College Network, and the Digital Medical Library Network (23). The framework developed by the MoHFW included five scenarios (32): (1) Patient to Registered Medical Practitioner; (2) Caregiver to Registered Medical Practitioner; (3) Health Worker to Registered Medical Practitioner; (4) Registered Medical Practitioner to Registered Medical Practitioner (31) and (5) Emergency Situations. The lack of clear policy and legislation has also deterred investments in telemedicine from the private sector. While a set of guidelines is available, it is neither comprehensive nor binding. There is no standardized format to qualify patient-physician interaction or to seek patient consent for privacy and confidentiality. Furthermore, there is no accountability framework to tackle medico-legal negligence matters or malpractice liabilities (31, 32). Sustained funding from the government to improve internet and telecommunications availability across the country, an extensive network of primary healthcare centers for service delivery, and a trained health workforce are critical to realizing NDHB proposal (33).

Bangladesh

Currently, no national telemedicine framework in Bangladesh exists; and current systems suffer from lack of technological infrastructure, healthcare inequities, and poor treatment quality (34). The current system is modeled on multiple hubs and spokes where consultations and training are provided between providers over video conferencing using Skype. The sub-district hospitals can consult district hospitals, which in turn can connect to central specialized hospitals. The system will benefit from gaps analyses to ensure that various aspects of telemedicine from infrastructure to privacy are adequately addressed. No comprehensive telemedicine efforts to boost capacity have been pursued amidst COVID-19.

China

China has a sizeable urban-rural health gap, which major telehealth networks such as the International MedioNet of China network, Golden Health Network, and the People's Liberation Army Telemedicine Network have not been able to rectify (34). In September 2018, the National Health Commission and the National Administration of Traditional Chinese Medicine released new e-healthcare rules to expand telehealth capabilities and develop the telehealth industry. This included guidance around a collaboration between commercial companies and hospitals, telehealth diagnosis, patient consent, and third-party collaborations (35). This broadened telemedicine definitions beyond physician-to-physician consultations to include physician-to-patient interactions, but still lacks some clarity in implementation and regulation (36). Like other Asian countries, online healthcare platforms are projected to see drastic increases in market share in the coming years, particularly following COVID-19, with companies supplying direct-to-patient telehealth subscriptions such as Good Doctor, Alibaba, and Tencent experiencing growth (36). China is also breaking new ground in terms of contactless innovations, such as a Smart Field Hospital trial in Wuhan during COVID-19, in which patient care is delivered through robots and digital devices (37).

Central Asian Region at a Glance-Focus on Kazakhstan

Kazakhstan implemented a national telemedicine network (NTMN) in 2004 (38). Its purpose was to eliminate the gap in the availability of specialized medical care for the urban and rural populations of the remote areas. This telehealth network combines 199 healthcare objects of districts, regions,

and republican organizations (38). Patients in regional and urban district hospitals receive teleconsultations from the doctors of regional hospitals and republican clinics of Almaty and Nur-Sultan cities in Kazakhstan. More than 500,000 telehealth consultations have been provided via video conferencing over the last 15 years. The first large-scale project in Kazakhstan, "*Development of telemedicine in rural health care,*" was launched in 2005 within the framework of the state program (39). During a typical session, doctors send the patient's data such as ultrasound, electrocardiography, X-rays, laboratory tests to the specialist consultant of the telemedicine center. The medical consultant gives his view for the diagnosis and recommendations for an additional examination and treatment. In 2018 a 5-year state program "*Digital Kazakhstan*" was run. Five critical areas, including medicine, are planned for digital transformation (40). As a part of the program, for the last 2 years, unified electronic medical records and doctor appointment mobile application systems have been implemented all over the country. In Kazakhstan, telemedicine is especially essential due to the nation's vast geographical spread and low population density. It is becoming increasingly crucial and being expanded to rural areas, 100–500 kilometers away from the city. In the COVID-19 era, telemedicine centers organize video consultations of patients with COVID-19 by sub-specialists, if necessary. The first COVID-19 case in Kazakhstan was confirmed on March 13, 2020, and more than 1,200 new cases have been confirmed to this date (41). At present, patients diagnosed with COVID-19 are being treated at regional hospitals. As soon as the first messages about COVID-19 were received, administration of the East Kazakhstan region established telehealth center headquarters at the premises of Semey Medical University (42). This experience was shared with other regions. The purpose of the headquarters is to limit exposure to physicians allowing doctors to consult with patients *via* videoconferencing. There is a mobile tablet at the patients' wards, which enables them to carry out visual monitoring and assessment of the patient's condition. The doctor who treats a patient in the department may request the consultation of their colleagues *via* videoconferencing, who are members of the headquarters, including: emergency physicians, pulmonologists, or infectious disease specialists. Telehealth enables access to consultations of any specialized health professional and, consequently, ensures the ensures the quality of care provided to the patients while avoiding exposure of the medical staff to potential CVOID-19 contagion. The positive experience of telehealth-laden headquarters has led to the Ministry of Health of the Republic of Kazakhstan and WHO proposing this model to be used in other regions of the country (42). Kazakhstan sets an example to other countries with a large geographical area but low-density populations in optimal use of telehealth platforms during COVID-19.

Spotlight on Africa

Sub-Saharan Africa is a region of swift telehealth development, as program implementation increases, and smartphone penetrance is expected to reach 66% by 2025 (43). This region suffers from the world's highest burden of disease and shortage of health workers, as well as barriers to telehealth implementation such as connectivity issues, limitations in device ownership, language barriers, high costs, and electricity access. This highlights the necessity for building supporting infrastructure, government support and involvement, upskilling of the workforce, and legislative compliance. Suzuki et al. reported that in countries such as South Africa, Egypt, Morocco, and Algeria, high internet and mobile penetration rates open up the possibility for telemedicine to compensate for large physician shortages (15). Economic development, mobile phone penetrance, and internet speed all need to be considered when considering future telemedicine possibilities. A systematic review of initiatives in Kenya showed that there were several eHealth projects, mostly focused on primary care and HIV/AIDS, but vast inequalities existed between more central and remote parts of the country in terms of delivery (44). In other African countries, such as Burkina Faso and Nigeria, lack of political support may be a cause of slow implementation (45). In 2014, the Health Professions Council of South Africa (HPCSA) released guidelines to deliver healthcare to underserved communities.

Telemedicine is still in its infancy in Africa due to ongoing conflicts and war, inadequate information communication technology (ICT), and lack of funding and political support for technology diffusion and policy (46). In light of the COVID-19 pandemic, disagreement between the HPCSA and the South African Medical Association ensued over matters such as the HPCSA's adversity to widespread telemedicine replacement over face-to-face consultations and requirement for previous face-to-face doctor-patient consultation (47). This resulted in amended guidelines in early April 2020. Africa in general, Sub-Saharan Africa in particular, suffer a high burden of disease and physician shortages and hence require international support to assist instigation of digital health efforts (48, 49). Digital health innovations such as mobile technologies offer a cost-effective strategy to improve health service delivery in Africa (50).

Focus on Latin America

Latin America has one of the fastest-growing elderly populations worldwide and has a big divide in access to healthcare providers between rural and urban regions (51). A 2019 study analyzed telemedicine expansion capabilities across 9 Latin American nations (52). It reported that since 2014, certain countries, including Peru, Colombia, Guatemala, Panama, Uruguay, Mexico, Costa Rica, Chile, and Argentina have developed a national telehealth strategy; other countries such as Panama, Mexico, and Guatemala do not have a national policy. It also reported an imbalance between public and private hospitals, with telehealth adoption in public hospitals being 30% higher. Notably, Chile has the highest telemedicine uptake in the region and has successfully transitioned from international funding to government funding (52). Innovative inter-country programs for myocardial infarction treatment have been set up, which facilitates linkages between patients in Columbia, Mexico, and Brazil through a centralized network (53). The Enlace Hispano-Americano de Salud (EHAS) Foundation also seeks to provide healthcare to rural Latin American communities through technology (54). It researches into communication networks, and how-to bring infrastructure to underdeveloped regions,

through means such as low-cost Wi-Fi solutions (54). In 2006, a Telemedicine University Network ("Rute") was set up in Brazil that connects 124 universities and teaching hospitals-making it, to our best knowledge, the biggest telemedicine/telehealth program in the world (55). Rute has allowed healthcare providers in Brazil to connect with their peers around the world, especially Portuguese speaking countries.

Targeted government support of telemedicine is needed in this region, as telemedicine in countries such as Mexico falls under the standard practice of medicine regulations, instead of being governed by a focused telehealth department (56). In 2018, the United Telemedicine Network was established in the Dominican Republic as a private network (57). As a result of COVID-19, telehealth is becoming increasingly popular in the region, with countries such as Brazil relaxing regulations for the duration of the pandemic. However, countries such as Argentina are still slow on the uptake of telemedicine (58). Overall, telemedicine adoption is becoming more widespread in Latin America, but certain regions need work before its full potential could be realized. This could be possible by implementing change management strategies with the support of various stakeholders.

Focus on the Caribbean

Telehealth in the Caribbean is in a relatively early stage, with a lack of cohesive telehealth strategies and policies. The National Health Authority in the Bahamas announced a new Electronic Health Record (EHR) system at the end of 2019 (59), which reduces the need for paper records and allows the effortless transfer of patient care, whilst the Dominican Republic is yet to have a national EHR system (60). Some burgeoning initiatives include a 2018 Telemedicine Pilot Project initiated by the Jamaican Minister of Health in the West Indies and the SickKids-Caribbean Initiative (SCI) that uses telemedicine to provide medical services for children with cancer and blood disorders across the Caribbean region (61, 62). Ongoing work is needed in this region to bring telehealth solutions to the broader population especially those from remote locations.

Focus on Australasia

Australia

Australia is in the process of making telehealth implementation more accessible for providers since the COVID-19 outbreak (63). New Medicare Benefits Scheme (MBS) items will allow access to telehealth services to all Australians with a Medicare card, and bulk-billing for all concession card holders (63). The MBS is a list of the medical services for which the Australian government pays Medicare rebates. Expansion of telehealth beyond primary care to specialist care with the help of relevant medical colleges and societies is currently being planned (64).

New Zealand

The Ministry of Health in New Zealand has released an advisory on available teleconsultation technologies for health care practitioners and best practices around patient privacy (65). The Medical Council of New Zealand has also released guidelines, particularly around prescription practice and the need for face-to-face consultation, whether that be in-person or via teleconference, before writing any scripts (66).

Focus on Europe and North America

Europe

The threat of COVID-19 in Europe has necessitated the need for telehealth platforms readily available to patients. Telehealth startups such as *French Doctolib* and *Qare*, Swedish LIVI, UK's Push Doctor, and Germany's Compugroup Medical SE have all seen considerable increases in European uptake numbers (67). In Europe, telemedicine is considered both a health service (Directive 2011/24/EU) and an information service (Directive 95/46/EU, Directive 2000/31/EC, and Directive 2002/58/EC). Due to lack of pan-European uniform medical liability and medical legislative regulations, a Europe-wide framework is far from being realized (68).

UK

In the United Kingdom (UK), telecommunication companies such as BT, Virgin Media, and Sky in the United Kingdom have agreed to support the National Health Services (NHS) in rolling out telehealth for healthcare practitioners (69). Primary care, clinical trials, counseling, and chronic disease reviews are all rapidly being moved to telehealth delivery (70). Prior to COVID-19, the government had already announced a centrally funded "Long Term Plan" to reduce the number of outpatients presentations (71). This had to be put into place much faster than anticipated as the need for telehealth to replace outpatient visits has drastically increased.

Italy

It has been reported that many Italian hospitals lack the infrastructure for effective telehealth platforms, due to supply-chain breakdown and insufficient internet capabilities (72). Italy also does not include telemedicine as an essential item to patients within its National Health Service (11). This is despite the implementation of telemedicine guidelines by the Italian Health Council in 2012, aimed at increasing telehealth penetration (73). Being one of the first countries to become overwhelmed by COVID-19, Italy was unprepared for the surging requirement of medical resources and personnel, and Italian physicians are urging other countries to avoid hospital-acquired transmission, wherever possible (74). No advisory on telemedicine was provided by the Italian health authorities until March 24 (75, 76), when an open call for telemedicine and monitoring system technologies were made by the Italian Health Ministry and Ministry for Technology Innovation and Digitalization jointly with the WHO (77).

France

The telemedicine regulations in France developed before COVID-19 allowed tertiary and primary care physicians to switch scheduled in-person consultations to teleconsultations, as and when appropriate (11). All video consultations and tele-expertise were allowed reimbursement, for those with COVID-19 or with COVID-19 symptoms, by the French National Health Insurance (NHI) by a decree signed by the Ministry of Health

on March 9, 2020, without the requirement of the patient being known to providers beforehand (78). This change was aimed to reduce exposure to providers and patients, and also to identify patients who are likely to be COVID-19 positive. On March 19, 2020, additional funding for follow-up *via* video or phone consultations by nurses were provided. This was expanded to include teleconsultations by speech therapists on March 25, 2020.

Spain

Spain, like Italy, has been overwhelmed by the current pandemic, and tertiary hospitals have had to adopt new telemedicine strategies rapidly. In 2012, Spain's national health authority launched a health IT strategy; however, it does not have a national policy that directly implicates telemedicine (79). To some extent, telemedicine adoption varies from region to region in Spain. Hospitals such as *Denia Marina Salud* Hospital have reported a rapid switch to telemedicine for outpatients and staff conferences to good effect (80). Interestingly, Spain's leading telehealth app, MediQuo, has now made consultations regarding COVID-19 free of charge (81).

United States

In the COVID-19 era, Medicare in the United States will now cover eligible telehealth consultations, and individual states are being encouraged to roll out Medicaid cover for such services (82, 83). Several commercial insurers have also followed suit in paying healthcare providers for telehealth services or are directly providing telehealth access to their members as part of benefits. The relaxation of prior regulations also includes an expansion of covered telehealth services and allowing new patients to be treated through telemedicine rather than only those with a prior relationship (84). Penalties for HIPAA violations for telemedicine are currently waived in the face of the COVID-19 pandemic when HCP are acting in good faith. Additionally, to facilitate telemedicine, practitioners licensed out of state and in good standing are allowed to practice across state lines. Furthermore, the Federal Communications Commission recently launched a $200 million Coronavirus Telehealth program (85). One of the challenges in the adoption of telemedicine has been the variations in uptake and differential policy frameworks across the different states. These variations merit a federal telemedicine policy initiative to harmonize and accelerate an overarching framework which would potentially improve its penetration across the United States.

Canada

In Canada, the availability of telehealth varies from province to province (86). A particular issue has been that telemedicine technology has primarily been allocated to rural services in the past, where now urban centers have a sudden need for them (87). However, the government has sought to rectify this by promising to increase the telehealth capabilities of healthcare facilities. The Royal College of Physicians and Surgeons of Canada has also put together a guideline for physicians from each province, outlining in which situations to use telemedicine and any changes to billing codes (88).

Telemedicine/Telehealth Application in Mental Health

Populations in LMICs, particularly those impacted by war, experience disproportionate levels of mental health burden compounded by lower levels of mental health treatment (89). Telehealth programs such as public health campaigns to reduce stigma and telehealth programs through mobile phones have shown effectiveness in Afghanistan and may be implemented in other LMICs (90). E-health, or digital health, in which mental health information can be sourced online, has implications for countries worldwide, as mobile phones are becoming increasingly prevalent. Individuals often go online to find information about mental illness, and hence digital platforms such as digital informative programs, not-for-profit organizations, and free helplines should receive ongoing international support (91).

Telehealth in Public Health Response and Community Engagement

In a public health crisis, telehealth could be a great tool to foster community engagement. Through targeted education programs aimed at training community leaders from underserved populations, telehealth could help to expand access to health care providers in remote areas. It could be used to provide medical services, including allied health services, and ongoing professional development of students and staff at remote healthcare facilities. Clinical supervision and mentoring could also use telehealth infrastructure (92). The coronavirus pandemic has shown that continuous learning, or rather e-learning is not only possible, but very effective, and can include a much wider group of people (93).

Telemedicine for Unstable Regions

A potential role of telemedicine can be realized in areas affected by war, ongoing violence and conflict, terrorism, and natural disasters (94–96). People inhabiting these regions suffer from an acute lack of basic medical provisions and access to health services. Telemedicine can complement and enhance the capacity of medical humanitarian agencies, organizations, or missions such as *Doctors Without Borders*. An international teleintensive care unit program was launched in 2012 to provide medical services in war-torn Syria (95). This model, leveraging telemedicine and artificial intelligence could also be deployed in other unstable regions to mitigate infectious disease vulnerability (IDV) in resource-limited settings such as the African countries (especially those in a civil war-like Burkina Faso) that scored lower than the average global health security (40.2) index. This could be important in building global health security while maintaining critical access and sustainability of health systems.

Language Barriers in Telemedicine in LMICs

Language barriers are associated with risks to patient safety and quality of care. They can pose a significant barrier in telemedicine uptake, specifically among culturally and linguistically diverse populations across low-resourced settings and developed regions

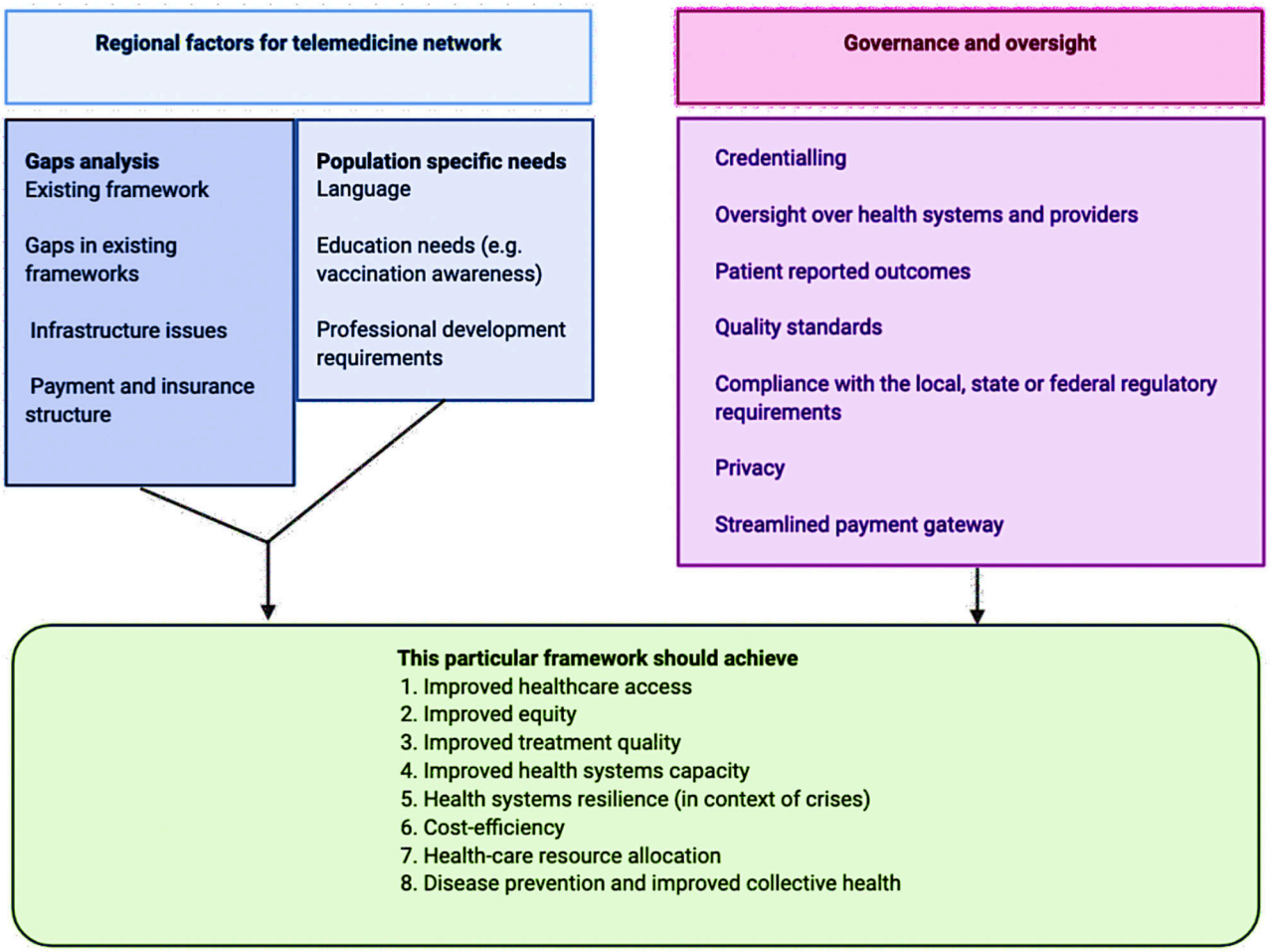

FIGURE 1 | Various regional and structural factors in telemedicine framework development and implementation.

alike, affecting providers and patients alike (9, 97–106). Communication barriers have been shown to impact patients adversely. With an increasingly diverse demographic makeup, patients from culturally and linguistically diverse backgrounds (CALD) or ethnic backgrounds are at increased risk of widening disparities in healthcare access and quality (107). Moreover, this population also consists of uninsured migrants or refugees who have limited knowledge of healthcare services and diseases that could be risk-managed (101, 107). Language barriers could potentially exacerbate the structural disparities, and therefore, telemedicine approaches should consider resources or technologies that could provide appropriate language support to the vulnerable communities (32).

DISCUSSION

Public health crisis, such as COVID-19, severely challenges the health systems (5, 7, 11). In this paper, we have critically examined the current state of telemedicine across geographics and the various steps taken amidst COVID-19 for its uptake and implementation. Some of the identified challenges/barriers and potential benefits to stakeholders are summarized in **Figure 1**. There is a compelling need for resources within individual states, countries, and regions to harmonize policies to establish an international framework on telemedicine (108). The consensus on uniform standards for telemedicine practices is missing. International organizations, including WHO, International Monetary Fund, World Economic Forum, and current consortium, could take the lead in facilitating such initiatives. The recommendations and considerations made by this consortium are to facilitate a policy-based international debate on the integration of telemedicine within the public health preparedness and response strategy during outbreaks (**Table 1**). We postulate that by identifying the gaps in policy, framework, and implementation, while considering various structural barriers and interfering factors, telemedicine would act as a "safety net" while mitigating the devastating impact of outbreaks such as COVID-19.

Regional frameworks that allow for collaboration and sharing of resources need to be strengthened. In pandemic settings, when existing health systems are under enormous stress,

open platforms for connectivity to use telemedicine and corresponding legislations to accommodate such provisions, so that telemedicine facilities could be readily available, in a secure manner while maintaining confidentiality and privacy in the doctor-patient relationship (33). Data sharing could also accelerate research programs by harnessing the data thus gathered. Commitment to equal access to quality care to all and digital health is a critical enabler for the overall transformation of the digital health ecosystem. Some barriers, such as technology and infrastructure specific to telemedicine in remote settings, including language barriers, need priority attention. Telehealth access is dependent on broadband access, smartphone usage and the presence of basic digital skills. A systematic review on the evaluation of barriers to telemedicine adoption worldwide found technology-specific barriers and lack of digital literacy as major impediments in telemedicine implementation (9). Not acknowledging and addressing these factors can further increase the digital disparity and lack of care access to those who may need it the most. This could be addressed through training, alternating in-person and telemedicine consultations, policy, and legislative changes, and change management strategies that consider local and cultural factors (9, 98). Digital literacy is a major barrier to telemedicine during COVID-19 (109).

Mainstreaming telemedicine in health systems could reduce healthcare inequities (110). Digital health is fast emerging as one of the most defining trends of this decade and will have a profound influence on geopolitical and socioeconomic realities in the future (111). Policies advocating the use of digital tools should be implemented that lays significant focus on the use of telemedicine services, especially in the Health and Well-ness Centers at the grassroots level wherein a mid-level provider/health worker can connect the patients to the doctors through technology platforms in providing timely and best possible care. This would improve efficiency, and clinical outcomes while also reducing costs of the healthcare system.

Therefore, for several countries, the fast implementation of telemedicine tools is still laborious and even impossible currently. Therefore, joint initiatives, like this consortium, might be instrumental in helping the governments to propose concrete solutions and policy directives to have these systems available. Despite advances in telemedicine and urgency in its deployment during COVID-19, people from vulnerable populations and/or from geographically disparate regions who have limited access to technologies may be at a disadvantage. Not all clinical examinations can be performed through telemedicine, and therefore, various clinical subspecialties need to develop guidelines for disease-specific telemedicine consultation programs complementing in-person appointments (7). Language and socioeconomic barriers need to be addressed along with maintaining patient continuity during COVID-19, including the need for in-person consultations when it is necessary.

An action plan centered around a global effort to integrate telemedicine into public health response to disease outbreaks such as COVID-19 is required (11). This would require embedding telemedicine as an integral part of national and international guidelines on health system preparedness (112). This along with international standards of interoperability can help widen telemedicine base (9). Barriers pertinent to digital divide needs to be addressed through targeted communication and engagement in respective languages on access and use of telemedicine. This has to be complemented with rigorous evaluation of telemedicine penetration and impact during public health emergencies or disease outbreaks. Beyond acute care, telerehabilitation is an important consideration, allowing long-term monitoring of patients who may require ongoing treatment and/or rehabilitation, especially those living in remote areas, where provision for traditional rehabilitation may be limited or relatively less accessible (113).

CONCLUSION

In conclusion, despite the variabilities in telemedicine uptake across the world; increasing evidence suggests a positive role for telehealth or telemedicine in improving health systems performance and outcomes in developed countries (114). In the COVID-19 era, telemedicine has taken a springboard trajectory, as governments and partnerships, thus made, have forged a way to support and accelerate its roll-out especially in developed countries. Telemedicine during COVID-19 has demonstrated organizations' ability to deliver quality care remotely (at home) while also reducing costs (115). This is likely to be sustained beyond the COVID-19 era with strengthening and widening of telemedicine services. However, in resource-constrained settings, a significant number of structural issues remain which have been exacerbated due to COVID-19. Moving further, one particular area warranting attention is improving telemedicine use among sub-specialities, complementing primary care. There is an emerging role of building partnerships between various stakeholders and promoting open innovations to allow benefits of telemedicine/telehealth to reach the disadvantaged populations/geographics (116). Regional efforts such as pan-European initiatives may be explored around appropriate regulation and governance frameworks once the COVID-19 period ends. International efforts toward developing public health preparedness framework, with telemedicine at the core of public health response during outbreaks such as COVID-19, are warranted.

AUTHOR'S NOTE

The COVID-19 pandemic is causing an unprecedented public health crisis impacting healthcare systems, healthcare workers, and communities. The COVID-19 Pandemic Health System REsilience PROGRAM (REPROGRAM) consortium is formed to champion the safety of healthcare workers, policy development, and advocacy for global pandemic preparedness and action.

AUTHOR CONTRIBUTIONS

SBh devised the project, the main conceptual ideas, including the proposal for a new telemedicine workflow, the proof outline, and coordinated the writing and editing of the manuscript. SBh and SBr wrote the first draft of the manuscript. SBh encouraged SBr to

investigate and supervised the findings of this work. All authors discussed the results and recommendations and contributed to the final manuscript.

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REFERENCES

1. World Health Organisation. *WHO Announces COVID-19 Outbreak A Pandemic.* (2020). Available online at: https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19 (accessed on March 11, 2020).
2. WHO. *WHO Coronavirus Disease (COVID-19) Dashboard.* (2020). Available onlibe at: https://covid19.who.int/ (accessed on September 11, 2020).
3. Slavitt A. The COVID-19 pandemic underscores the need to address structural challenges of the US health care system. *JAMA Health Forum*. (2020) 1:e200839. doi: 10.1001/jamahealthforum.2020.0839
4. Bhaskar S, Bradley S, Israeli-Korn S, Menon B, Chattu VK, Thomas P, et al. Chronic neurology in COVID-19 Era: clinical considerations and recommendations from the REPROGRAM consortium. *Front Neurol.* (2020) 11:664. doi: 10.3389/fneur.2020.00664
5. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) settings: recommendations from the REPROGRAM consortium. *Front Cardiovasc Med.* (2020) 7:112. doi: 10.3389/fcvm.2020.00112
6. Bhaskar S, Sharma D, Walker AH, McDonald M, Huasen B, Haridas A, et al. Acute neurological care in the COVID-19 Era: the pandemic health system rEsilience PROGRAM (REPROGRAM) consortium pathway. *Front Neurol.* (2020) 11:579. doi: 10.3389/fneur.2020.00579
7. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system REsilience PROGRAM (REPROGRAM) international consortium (Part 2). *Front Public Health.* (2020) 8:410. doi: 10.3389/fpubh.2020.00410
8. World MR. *Global Telehealth Market Size, Status and Forecast 2020-2026.* (2020). Available online at: https://www.marketreportsworld.com/enquiry/request-sample/14569204 (accessed July 15, 2020).
9. Scott Kruse C, Karem P, Shifflett K, Vegi L, Ravi K, Brooks M. Evaluating barriers to adopting telemedicine worldwide: a systematic review. *J Telemed Telecare.* (2018) 24:4–12. doi: 10.1177/1357633x16674087
10. Dylan S. Vox. *Coronavirus Is Exposing All of the Weaknesses in the US Health System.* (2020). Available online at: https://www.vox.com/policy-and-politics/2020/3/16/21173766/coronavirus-covid-19-us-cases-health-care-system (accessed on September 12, 2020).
11. Ohannessian R, Duong TA, Odone A. Global telemedicine implementation and integration within health systems to fight the COVID-19 pandemic: a call to action. *JMIR Public Health Surveill.* (2020) 6:e18810. doi: 10.2196/18810
12. WHO Global Observatory for eHealth. *Telemedicine: Opportunities and Developments in Member States: Report on the Second Global Survey on eHealth.* (2010). Geneva. Available online at: https://apps.who.int/iris/handle/10665/44497 (accessed 2010)
13. Toledo C. *A five-stage model of computer technology integration into teacher education curriculum.* Contemporary Issues in Technology and Teacher Education. (2005). p. 5.
14. Saigí-Rubió F, Torrent-Sellens J, Ramos I, Sáez C, Kotzeva A, Villalobos J. *Framework for the Implementation of a Telemedicine Service*. Washington, DC: Pan American Health Organization (2016).
15. Suzuki T, Hotta J, Kuwabara T, Yamashina H, Ishikawa T, Tani Y, et al. Possibility of introducing telemedicine services in Asian and African countries. *Health Policy Technol.* (2020) 9:13–22. doi: 10.1016/j.hlpt.2020.01.006
16. Aljazeera. *Digital Doctors: Indonesia Uses 'telehealth' to Fight Coronavirus*. (2020). Available online at: https://www.aljazeera.com/ajimpact/digital-doctors-indonesia-telehealth-fight-coronavirus-200410055639003.html (accessed on April 10, 2020).
17. Koh, D. Mobihealth News (2020). *Doctor Anywhere to Launch COVID-19 Medical Advisory Clinic*. Available online at: https://www.mobihealthnews.com/news/asia-pacific/doctor-anywhere-launch-covid-19-medical-advisory-clinic (accessed on April 4, 2020).
18. Ministry of Health Singapore. *Licensing Experimentation and Adaptation Programme (LEAP) - A MOH Regulatory Sandbox.* (2019). Available online at: https://www.moh.gov.sg/home/our-healthcare-system/licensing-experimentation-and-adaptation-programme-(leap)---a-moh-regulatory-sandbox (accessed on April 21, 2020).
19. Health Service Authority. *Regulatory Guidelines for Telehealth Products.* (2019). Available online at: https://www.hsa.gov.sg/docs/default-source/hprg-mdb/regulatory-guidelines-for-telehealth-products-rev-2-1.pdf (accessed on April 21, 2020).
20. Yap J. *From Telemedicine To Cloud Kitchen: COVID-19 Reveals 4 Key Business Opportunities In S'pore.* (2020). Available online at: https://vulcanpost.com/695442/covid-19-business-opportunities-singapore/ (accessed on April 21, 2020).
21. Min A. Channel News Asia. *COVID-19: CHAS, MediSave to be Extended to Cover Video Consultations for 7 Chronic Conditions.* (2020). Available online at: https://www.channelnewsasia.com/news/singapore/covid-19-chas-medisave-video-consultation-chronic-conditions-12594900 (accessed on April 21, 2020).
22. Singapore Medical Association Telemedicine Workgroup. *Leveraging on Telemedicine during an Infectious Disease Outbreak.* (2020). Available online at: https://www.sma.org.sg/UploadedImg/files/ncov2019/LeveragingTelemedicineInfectiousDiseaseOutbreak20200212.pdf (accessed on April 26, 2020).
23. Ministry of Health and Family Welfare of India. *Telemedicine Practice Guidelines. Enabling Registered Medical Practitioners to Provide Healthcare Using Telemedicine.* (2020). Available online at: https://www.mohfw.gov.in/pdf/Telemedicine.pdf (accessed on April 21, 2020).
24. Medical Council of India. *Telemedicine Practice Guidelines.* (2020). Available online at: https://www.mohfw.gov.in/pdf/Telemedicine.pdf (accessed on April 21, 2020).
25. Ministry of Family Health and Welfare, Government of India. *National Health Policy.* (2020). Available online at: https://www.nhp.gov.in/nhpfiles/national_health_policy_2017.pdf (accessed on April 21, 2020).
26. Ministry of Family Health and Welfare, Government of India. *National Digital Health Blueprint.* (2020). Available online at: https://main.mohfw.gov.in/newshighlights/final-report-national-digital-health-blueprint-ndhb (accessed on April 20, 2020).
27. eSanjeevaniOPD. *National TeleConsultation Service, Ministry of Health and Family Welfare.* (2020). Available online at: https://esanjeevaniopd.in/Home (accessed on September 12, 2020).
28. IndiaToday. *Independence Day: PM Modi Launches National Digital Health Mission.* (2020). Available online at: https://www.indiatoday.in/india/story/

independence-day-speech-pm-modi-launches-national-digital-health-mission-1711399-2020-08-15 (accessed on September 12, 2020).
29. Chellaiyan V, Nirupama AY, Taneja N. Telemedicine in India: Where do we stand? *J Family Med Primary Care*. (2019) 8:1872. doi: 10.4103/jfmpc.jfmpc_264_19
30. Jhunjhunwala, A. ET Health World. *Telemedicine in India–Overpromising and Underdelivering*. (2020). Available online at: https://health.economictimes.indiatimes.com/news/industry/telemedicine-in-india-overpromising-and-underdelivering-ayesha-jhunjhunwala/72878097 (accessed on April 21, 2020).
31. Mishra S, Singh I, Chand R, (editors). Current status of telemedicine network in India and future perspective. In: *Proceedings of the Asia-Pacific Advanced Network*. Colorado (2012).
32. Ateriya N, Saraf A, Meshram VP, Setia P. Telemedicine and virtual consultation: the Indian perspective. *Natl Med J India*. (2018) 31:215–8. doi: 10.4103/0970-258x.258220
33. Ranganathan S. *Towards a Holistic Digital Health Ecosystem in India: Observer Research Foundation.* (2020). ORF Issue Brief No. 351. Available online at: https://www.orfonline.org/research/towards-a-holistic-digital-health-ecosystem-in-india-63993 (accessed 21 2020).
34. Ali A, Faisal A, Sorwar G, editors. Telemedicine framework for Bangladesh. *TENCON 2010 - 2010 IEEE Region 10 Conference*. (2010). p. 21-24 Nov. 2010.
35. Chen C, Balzano J. Covington Digital Health. *China Expands Regulations on e-Healthcare Issues.* (2018). Available online at: https://www.covingtondigitalhealth.com/2018/10/china-expands-regulations-on-e-healthcare-issues/ (accessed on April 21, 2020).
36. Wang K. Mondaq. *China's Health Authorities Issue New Rules on Telemedicine.* (2018). Available online at: https://www.mondaq.com/china/healthcare/739798/china39s-health-authorities-issue-new-rules-on-telemedicine (accessed on April 21, 2020).
37. Hornyak T. CNBC. *What America Can Learn From China's Use of Robots and Telemedicine to Combat the Coronavirus.* (2020). Available online at: https://www.cnbc.com/2020/03/18/how-china-is-using-robots-and-telemedicine-to-combat-the-coronavirus.html (accessed on April 21, 2020).
38. Hamilton C. *Telemedicine in Kazakhstan: Bridging the Urban–Rural Divide in Delivering Prevention, Diagnosis, and Treatment of Noncommunicable Diseases*. World Health Organization Regional Office for Europe, Division of Health Systems and Public Health (2018).
39. Ezdrav. *Republican Electronic Health Center. Telemedicine in the Republic of Kazakhstan.* (2020). Available online at: http://ezdrav.kz/posetitelyam/telemeditsina (accessed on April 16, 2020).
40. Yensebayev, R. Astana Times. *Digital Kazakhstan: Transforming Through Modern Technology.* (2018). Available online at: https://astanatimes.com/2018/02/digital-kazakhstan-transforming-through-modern-technology/ (accessed on April 16, 2020).
41. Garda World. *Kazakhstan Government Confirms First Cases of COVID-19.* (2020). Available online at: https://www.garda.com/crisis24/news-alerts/322526/kazakhstan-government-confirms-first-cases-of-covid-19-march-13-update-7 (accessed on April 16, 2020).
42. Semey Medical University. *MUS NAO was visited by the Deputy Chairman of the Committee for Quality and Safety Control of Goods and Services of the Ministry of Health of the Republic of Kazakhstan.* (2020). Available online at: https://semeymedicaluniversity.kz/2020/04/13/nao-mus-posetil-zamestitel-predsedatelya-komiteta-kontrolya-kachestva-i-bezopasnosti-tovarov-i-uslug-mz-rk/ (accessed on April 13, 2020).
43. Holst C, Sukums F, Radovanovic D, Ngowi B, Noll J, Winkler AS. Sub-Saharan Africa—the new breeding ground for global digital health. *Lancet Digital Health*. (2020) 2:e160–e2. doi: 10.1016/S2589-7500(20)30027-3
44. Njoroge M, Zurovac D, Ogara EAA, Chuma J, Kirigia D. Assessing the feasibility of eHealth and mHealth: a systematic review and analysis of initiatives implemented in Kenya. *BMC Res Notes*. (2017) 10:90. doi: 10.1186/s13104-017-2416-0
45. Wamala DS, Augustine K. A meta-analysis of telemedicine success in Africa. *J Pathol Inform*. (2013) 4:6. doi: 10.4103/2153-3539.112686
46. Shiferaw F, Zolfo M. The role of information communication technology (ICT) towards universal health coverage: the first steps of a telemedicine project in Ethiopia. *Glob Health Action*. (2012) 5:1–8. doi: 10.3402/gha.v5i0.15638
47. Davidow R, Ferreira A. Clydeco. *COVID-19 South Africa: Pandemic and Telemedicine.* (2020). Available online at: https://www.clydeco.com/insight/article/covid-19-south-africa-pandemic-and-telemedicine (accessed on April 21, 2020).
48. Geissbuhler A, Bagayoko CO, Ly O. The RAFT network: 5 years of distance continuing medical education and tele-consultations over the Internet in French-speaking Africa. *Int J Med Inform*. (2007) 76:351–6. doi: 10.1016/j.ijmedinf.2007.01.012
49. Geissbuhler A, Ly O, Lovis C, L'Haire J-F. Telemedicine in Western Africa: lessons learned from a pilot project in Mali, perspectives and recommendations. *AMIA Annu Symp Proc*. (2003) 2003:249–53.
50. Nachega JB, Leisegang R, Kallay O, Mills EJ, Zumla A, Lester RT. Mobile health technology for enhancing the COVID-19 response in africa: a potential game changer? *Am J Trop Med Hyg*. (2020) 103:3–5. doi: 10.4269/ajtmh.20-0506
51. Figliuoli L, Flamini V, Lambert F, Mowatt R. International Monetary Fund. *Is Latin America Prepared for an Aging Population?* (2018). Available online at: https://www.imf.org/en/News/Articles/2018/12/11/blog-is-latin-america-prepared-for-an-aging-population (accessed on September 11, 2020).
52. LeRouge CM, Gupta M, Corpart G, Arrieta A. Health system approaches are needed to expand telemedicine use across nine latin american nations. *Health Affairs*. (2019) 38:212–21. doi: 10.1377/hlthaff.2018.05274
53. Mehta S, Botelho R, Fernandez F, Perin M, Dusilek C, Cardoso R, et al. TCT-393 Latin America Telemedicine Infarct Network (LATIN) – Telemedicine + STEMI systems of care to hugely expand access to AMI care in emerging countries. *J Am College Cardiol.* (2017) 70(18 Suppl):B161. doi: 10.1016/j.jacc.2017.09.490
54. The Enlace Hispano-Americano de Salud (EHAS) (2020). *NAPO: Social Innovation With Connectivity and Health.* Available online at: http://www.ehas.org/que-hacemos/investigacion-y-desarrollo/napo-social-innovation-with-connectivity-and-health/ (accessed April 21, 2020).
55. Messina L. In the field stories (2017). Brazil breaks new ground with an advanced telemedicine network. Available from: https://www.inthefieldstories.net/brazil-breaks-new-ground-with-advanced-telemedicine-network/ (accessed on April 23, 2020).
56. Ferreira W, Rosales A. Mondaq. *International Telemedicine: A Global Regulatory Challenge.* (2020). Available online at: https://www.mondaq.com/unitedstates/Food-Drugs-Healthcare-Life-Sciences/904170/International-Telemedicine-A-Global-Regulatory-Challenge (accessed on April 21, 2020).
57. Dominican Today. *From the Dominican Republic to the World: United Telemedicine Network.* (2017). Available online at: https://dominicantoday.com/dr/economy/2017/01/24/from-the-dominican-republic-to-the-world-united-telemedicine-network/ (accessed on April 21, 2020).
58. BN Americas. *Is COVID-19 the Push e-Health Needed?* (2020). Available online at: https://www.bnamericas.com/en/features/is-covid-19-the-push-e-health-needed (accessed on April 21, 2020).
59. National Health Insurance Authority (NHIA), Bahamas. *NHI has Launched the Electronic Health Record.* (2019). Available online at: https://www.nhibahamas.gov.bs/nhi-launch-ehr/ (accessed on April 21, 2020).
60. World Health Organisation. *Dominican Republic*. (2016). Available online at: http://origin.who.int/goe/publications/atlas/2015/dom.pdf (accessed September 12, 2020).
61. Garfield A. *Telemedicine Pilot Project Jamaica: Jamaica Information Service.* (2018). Available online at: https://jis.gov.jm/telemedicine-pilot-project/ (accesssed on April 21, 2020).
62. Adler E, Alexis C, Ali Z, Allen U, Bartels U, Bick C, et al. Bridging the distance in the caribbean: telemedicine as a means to build capacity for care in paediatric cancer and blood disorders. *Stud Health Technol Inform*. (2015) 209:1–8.
63. Australian Government, Department of Health (2020). *Coronavirus (COVID-19): National Health Plan Resources*. Available online at: https://www.health.gov.au/resources/collections/coronavirus-covid-19-national-health-plan-resources (accessed on April 21, 2020).

64. Australian Government, Department of Health. *COVID-19: Whole of Population Telehealth for Patients, General Practice, Primary Care and Other Medical Services.* (2020). Available online at: https://www.health.gov.au/ (accessed on April 21, 2020).
65. Newzealand Government, Ministry of Health. *Information Sharing Advice for Health Care Workers.* (2020). Available online at: https://www.health.govt.nz/system/files/documents/pages/covid-19-information-sharing-advice-for-health-care-workers-31mar2020.pdf (accessed on March 31, 2020).
66. Medical Council of Newzealand. *Statement on Telehealth.* (2020). Available online at: http://www.mcnz.org.nz/ (accessed on April 21, 2020).
67. Business Times Singapore. *Covid-19 Drives Europe Patients to Virtual Doctors.* (2020). Available online at: https://www.businesstimes.com.sg/technology/covid-19-drives-europe-patients-to-virtual-doctors (accessed on April 19, 2020).
68. Raposo VL. Telemedicine: the legal framework (or the lack of it) in Europe. *GMS Health Technol Assess.* (2016) 12:Doc03. doi: 10.3205/hta000126
69. Porter S. *Pledge by Telecommunications Industry to Support NHS During COVID-19.* healthcare IT News (2020) [cited 2020 April 19]. Available online at: https://www.healthcareitnews.com/news/europe/pledge-telecommunications-industry-support-nhs-during-covid-19.
70. Greenhalgh T, Wherton J, Shaw S, Morrison C. Video consultations for covid-19. *BMJ.* (2020) 368:m998. doi: 10.1136/bmj.m998
71. O'Cathail M, Sivanandan MA, Diver C, Patel P, Christian J. The use of patient-facing teleconsultations in the national health service: scoping review. *JMIR Med Inform.* (2020) 8:e15380. doi: 10.2196/15380
72. Webster P. Virtual health care in the era of COVID-19. *Lancet*. (2020) 395:1180–1. doi: 10.1016/S0140-6736(20)30818-7
73. Diamond F. Infection Control Today (2020). *Fight COVID-19 With Telemedicine*. Available online at: https://www.infectioncontroltoday.com/view/fight-covid-19-telemedicine (accessed on April 21, 2020).
74. Begley, S. Stat News. *A Plea From Doctors in Italy: To Avoid Covid-19 Disaster, Treat More Patients at Home.* (2020). Available online at: https://www.statnews.com/2020/03/21/coronavirus-plea-from-italy-treat-patients-at-home/ (accessed on April 21, 2020).
75. Paterlini M. On the front lines of coronavirus: the Italian response to COVID-19. *BMJ.* (2020) 368:m1065. doi: 10.1136/bmj.m1065
76. Remuzzi A, Remuzzi G. COVID-19 and Italy: what next? *Lancet*. (2020) 395:1225–8. doi: 10.1016/S0140-6736(20)30627-9
77. Innova per l'Italia. *La tecnologia e l'innovazione per la lotta al Coronavirus: Le fast call.* (2020). Available online at: https://innovaperlitalia.agid.gov.it/call2action/index.html (accessed on September 12, 2020).
78. Legifrance.gouv.fr. *Décret n° 2020-227 du 9 mars 2020 adaptant les conditions du bénéfice des prestations en espèces d'assurance maladie et de prise en charge des actes de télémédecine pour les personnes exposées au covid-19.* (2020). Available online at: https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000041704122&categorieLien=id (accessed September 12, 2020).
79. Momentum. *Telemedicine in Spain.: Momentum.* (2012). Available online at: http://www.telemedicine-momentum.eu/spain/ (acessed on April 21, 2020).
80. Rouger M. *COVID-19 Pandemic Expedites a Cultural Change in Healthcare: Healthcare in Europe.* (2020). Available online at: https://healthcare-in-europe.com/en/news/covid-19-pandemic-expedites-a-cultural-change-in-healthcare.html (accessed April 19, 2020).
81. MediQuo (2020). Available online at: https://www.mediquo.com/ (accessed on April 19, 2020).
82. United States Government (2020). *Telehealth in United States*. Available online at: https://www.medicare.gov/coverage/telehealth (accessed on September 11, 2020).
83. United States Government. *Medicaid State Plan Fee-for-Service Payments for Services Delivered Via Telehealth.* (2020). Available online at: https://www.medicaid.gov/medicaid/benefits/downloads/medicaid-telehealth-services.pdf (accessed on April 19, 2020).
84. American Academy of Family Physicians. *Using Telehealth to Care for Patients During the COVID-19 Pandemic.* Available online at: https://www.aafp.org/patient-care/emergency/2019-coronavirus/telehealth.html (accessed on April 19, 2020).
85. Mazur L, Van Demark D. National Law Review (2020). *$200 Million of Funding for COVID-19 Telehealth Program*. Available online at: https://www.natlawreview.com/article/200-million-funding-covid-19-telehealth-program (accessed on April 19, 2020).
86. BBD. *Provincial Telehealth Resources: An Interactive Map of Canada.* (2020). Available online at: https://www.bbd.ca/blog/telehealth-resources-canada/ (accessed on September 11, 2020).
87. Mahal I. The Conversation. *Coronavirus has SPed up Canada's Adoption of Telemedicine.* (2020). Let's make that change permanent. Available online at: https://theconversation.com/coronavirus-has-sped-up-canadas-adoption-of-telemedicine-lets-make-that-change-permanent-134985 (accessed on April 21, 2020).
88. Royal College of Physicians and Surgeons of Canada. *Telemedicine and Virtual Care Guidelines (and Other Clinical Resources for COVID-19).* (2020). Available online at: http://www.royalcollege.ca/rcsite/documents/about/covid-19-resources-telemedicine-virtual-care-e (accessed on April 19, 2020).
89. Bruckner TA, Scheffler RM, Shen G, Yoon J, Chisholm D, Morris J, et al. The mental health workforce gap in low- and middle-income countries: a needs-based approach. *Bull World Health Organ.* (2011) 89:184–94. doi: 10.2471/blt.10.082784
90. Khoja S, Scott R, Husyin N, Durrani H, Arif M, Faqiri F, et al. Impact of simple conventional and Telehealth solutions on improving mental health in Afghanistan. *J Telemed Telecare.* (2016) 22(8):495-8. doi: 10.1177/1357633x16674631
91. Services for Australian Rural and Remote Allied Health (SARRAH). *Telehealth and Allied Health Position Paper.* (2012). Available online at: https://sarrah.org.au/publication/allied-health-and-telehealth-position-paper (accessed on September 12, 2020).
92. Rose S. Medical Student Education in the Time of COVID-19. *JAMA*. (2020) 323:2131–2. doi: 10.1001/jama.2020.5227
93. Mian A, Khan S. Medical education during pandemics: a UK perspective. *BMC Med.* (2020) 18:100. doi: 10.1186/s12916-020-01577-y
94. Kealy A, Stapleton L. Telemedicine systems development in post-conflict contexts: a country case study of the role of symbols of conflict in systems engineering. *IFAC Proceedings Volumes*. (2012) 45:120–5. doi: 10.3182/20120611-3-IE-4029.00024
95. Moughrabieh A, Weinert C. Rapid deployment of international tele-intensive care unit services in war-torn syria. *Ann Am Thorac Soc*. (2016) 13:165–72. doi: 10.1513/AnnalsATS.201509-589OT
96. Bigna JJ, Noubiap JJ, Plottel CS, Kouanfack C, Koulla-Shiro S. Barriers to the implementation of mobile phone reminders in pediatric HIV care: a pre-trial analysis of the Cameroonian MORE CARE study. *BMC Health Serv Res*. (2014) 14:523. doi: 10.1186/s12913-014-0523-3
97. Scholl J, Syed-Abdul S, Ahmed LA. A case study of an EMR system at a large hospital in India: challenges and strategies for successful adoption. *J Biomed Inform*. (2011) 44:958–67. doi: 10.1016/j.jbi.2011.07.008
98. Meuter RFI, Gallois C, Segalowitz NS, Ryder AG, Hocking J. Overcoming language barriers in healthcare: a protocol for investigating safe and effective communication when patients or clinicians use a second language. *BMC Health Services Res.* (2015) 15:371. doi: 10.1186/s12913-015-1024-8
99. Diamond LC, Wilson-Stronks A, Jacobs EA. Do hospitals measure up to the national culturally and linguistically appropriate services standards? *Med Care*. (2010) 48:1080–7. doi: 10.1097/MLR.0b013e3181f380bc
100. Doty M. Commonwelath Fund. *Hispanic Patients' Double Burden: Lack of Health Insurance and Limited English.* (2003). Available online at: www.commonwealthfund.org (accessed on September 12, 2020).
101. Flores G, Abreu M, Barone CP, Bachur R, Lin H. Errors of medical interpretation and their potential clinical consequences: a comparison of professional versus ad hoc versus no interpreters. *Ann Emerg Med*. (2012) 60:545–53. doi: 10.1016/j.annemergmed.2012.01.025
102. Hasnain-Wynia R, Yonek J, Pierce D, Kang R, Greising C. Hospital langague services for patients with limited English proficiency: results from a national survey. *Health Research & Educational Trust and National Health Law Program*. California (2006).
103. Ponce NA, Hays RD, Cunningham WE. Linguistic disparities in health care access and health status among older adults. *J Gen Intern Med*. (2006) 21:786–91. doi: 10.1111/j.1525-1497.2006.00491.x

104. Cordasco KM, Ponce NA, Gatchell MS, Traudt B, Escarce JJ. English language proficiency and geographical proximity to a safety net clinic as a predictor of health care access. *J Immigr Minor Health*. (2011) 13:260–7. doi: 10.1007/s10903-010-9425-6
105. Baskar PS, Cordato D, Wardman D, Bhaskar S. In-hospital acute stroke workflow in acute stroke - systems-based approaches. *Acta Neurol Scand*. (2020) 41:707–12. doi: 10.1111/ane.13343
106. Bhaskar S, Thomas P, Cheng Q, Clement N, McDougall A, Hodgkinson S, et al. Trends in acute stroke presentations to an emergency department: implications for specific communities in accessing acute stroke care services. *Postgrad Med J*. (2019) 95:258–64. doi: 10.1136/postgradmedj-2019-136413
107. Nathenson RA, Saloner B, Richards MR, Rhodes KV. Spanish-speaking immigrants' access to safety net providers and translation services across traditional and Emerging US destinations. *Milbank Q*. (2016) 94:768–99. doi: 10.1111/1468-0009.12231
108. Bali S. Barriers to Development of Telemedicine in Developing Countries. In: Heston TF, editor. *Telehealth*. London: IntechOpen (2018). doi: 10.5772/intechopen.81723
109. Triana AJ, Gusdorf RE, Shah KP, Horst SN. Technology literacy as a barrier to telehealth during COVID-19. *Telemed J E Health*. (2020) 26:1118–9. doi: 10.1089/tmj.2020.0155
110. WHO Regional Office for Europe. *How Health Systems Can Address Health Inequities Through Improved Use of Structural Funds*. (2010). Copenhagen. Available online at: https://www.euro.who.int/en/publications/abstracts/how-health-systems-can-address-health-inequities-through-improved-use-of-structural-funds (accessed on September 12, 2020).
111. Mesko B. Health IT and digital health: the future of health technology is diverse. *J Clin Transl Res*. (2018) 3(Suppl 3): 431–4. doi: 10.18053/jctres.03.2017S3.006
112. World Health Organization Regional Office for Europe. *Strengthening the Health Systems Response to COVID-19*. (2020). Technical guidance #1: Maintaining continuity of essential health care services while mobilizing the health workforce for COVID-19 response. Available online at: shorturl.at/qvQU1 (accessed September 12, 2020).
113. Peretti A, Amenta F, Tayebati SK, Nittari G, Mahdi SS. Telerehabilitation: review of the State-of-the-art and areas of application. *JMIR Rehabil Assist Technol*. (2017) 4:e7. doi: 10.2196/rehab.7511
114. Rao B, Lombardi A. Telemedicine: current status in developed and developing countries. *J Drugs Dermatol*. (2009) 8:371–5.
115. Temesgen ZM, DeSimone DC, Mahmood M, Libertin CR, Varatharaj Palraj BR, Berbari EF. Mayo clinic strategies for COVID-19 health care after the COVID-19 pandemic and the influence of telemedicine. *Mayo Clinic Proc*. (2020) 95:S66–8. doi: 10.1016/j.mayocp.2020.06.052
116. Curioso WH. Building capacity and training for digital health: challenges and opportunities in latin America. *J Med Internet Res*. (2019) 21:e16513. doi: 10.2196/16513

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OPINION
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Telemedicine in Long-Term Care Facilities During and Beyond COVID-19: Challenges Caused by the Digital Divide

Alexander Seifert[1,2]*, *John A. Batsis*[3] and *Anthony C. Smith*[4,5,6]

[1] Center for Gerontology, University of Zurich, Zurich, Switzerland, [2] School of Social Work, Institute for Integration and Participation, University of Applied Sciences and Arts Northwestern Switzerland, Olten, Switzerland, [3] Division of Geriatric Medicine, Department of Nutrition, Center for Aging & Health, Gillings School of Global Public Health, University of North Carolina at Chapel Hill School of Medicine, Chapel Hill, NC, United States, [4] Centre for Online Health, The University of Queensland, Brisbane, QLD, Australia, [5] Centre for Health Services Research, The University of Queensland, Brisbane, QLD, Australia, [6] Centre for Innovative Technology, University of Southern Denmark, Odense, Denmark

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***Correspondence:**
Alexander Seifert
alexander.seifert@fhnw.ch

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BACKGROUND

The COVID-19 pandemic has especially limited older adults from engaging in personal contact with others, as they have been classified as a high-risk population (1, 2). Increasing evidence shows that COVID-19 has taken a particularly heavy toll on older adults in long-term care facilities (LTCFs) (3). Older residents of LTCFs (e.g., nursing homes, retirement homes) often have daily care needs and are at especially high risk of COVID-19 due to the existence of multiple medical comorbidities and pre-existing conditions (4). As such, measures have often been put in place where such patients must shelter in place, maintain physical distancing from others during the pandemic and be subject to quarantine if they need to leave the facility for medical care. The context of living in LTCF means that older adults may be subject to even more protective measures that are administratively mandated, more so than the general population, including preventing their loved ones from visiting.

Telemedicine (also referred to as telehealth) has been recently shown to play an important role in distance-based treatment during this pandemic (5–8), despite the lack of quality, evidence-based trials that exist (9). Telemedical solutions are often feasible and acceptable in delivering care to older adults in LTCFs, even in those with sensory impairments such as hearing or visual loss (9). However, older adults are less likely than younger people to be able to take advantage of the opportunities enabled by modern information and communication technology (ICT) or telemedicine (10–14). Older adults living in LTCFs often (a) opt not to use the internet, (b) cannot afford internet access or ICT devices, (c) lack technical solutions with which to use telemedicine to connect virtually with doctors or other health professionals, (d) have physical or cognitive limitations that may limit possible telemedicine use or prevent them from using telemedicine at all without assistance, and (e) lack the skills to use ICT or telemedicine even if they do have access (9, 11, 15–18). Furthermore, the institutional may prevent the individual use of telemedicine; for example, individual use may depend on internet availability, ICT access, and telemedicine tools/software at a given facility. This article will outline and discuss the problems in this field and make recommendations for future discussion.

ICT USE IN LONG-TERM CARE FACILITIES

While modern ICT use (such as the use of the internet, smartphones, and tablets) in healthy older adults has increased precipitously in recent years, the situation differs for those with multiple medical comorbidities and functional impairments and those with advanced age who are the primary residents of LTCFs (19–23). Seifert and Cotten (19) showed in their 2019 study that 21% of retirement home residents used the internet, 13% used a smartphone, and 5% used a tablet. Compared with non-users, internet users within LTCFs were more likely to be younger, healthier, and more functionally unimpaired (23, 24). The residents in this study (19) were also asked about their difficulties with modern technology with the statement, "Do you have difficulty operating modern technical devices?" Respondents rated the statement based on a 5-point Likert scale format (1 = "No, not at all" to 5 = "Yes, very much"). Among the respondents, 6.3% answered "No, not at all," 10.1% answered "Not very much," 26.9% answered "Partly," 34.3% answered "Yes, somewhat," and 22.5% answered "Yes, very much." Schlomann et al. (22) recently conducted a study using data from North-Rhine–Westphalia, Germany, involving people aged 80 years and older living in private households and LTCFs. The researchers found that fewer than 3% of people in LTCFs used internet-connected ICT devices. ICT-device adoption was associated with the living environment and individual characteristics, including functional health, chronological age, education, and technology interest (22). These results indicate that individual characteristics and the living environment are both related to technology usage among the oldest age groups (21, 24).

TELEMEDICINE AND DIGITAL INFRASTRUCTURE IN LONG-TERM CARE

Whether LTCF residents have access to using telemedicine is highly dependent on an underlying telemedicine infrastructure (e.g., internet availability, ICT access, telemedicine tools/software, ICT skills). The availability of modern ICT is limited within LTCFs, thus highlighting a significant deficiency in ICT infrastructure (25, 26). This deficit, in part, also includes a lack of technical skills among LTCF staff and potentially their apprehension of using technology within care facilities (27, 28), all inhibiting opportunities for telemedicine. The ongoing COVID-19 pandemic has prompted discussions of the positive outcomes of telemedicine for residents of LTCFs (29, 30). However, these discussions have also created awareness of the existing limitations of these facilities' current telemedicine infrastructures (11, 31).

Based on a Swiss representative national study (32) among managers of 466 LTCFs conducted in winter 2019, 14.6% of the LTCFs in Switzerland did not provide internet access to their residents. The survey was carried out as a standardized online survey of inpatient old-age homes throughout Switzerland. The respective managers were interviewed (32). Of the institutions that provided internet access, 66.3% offered residents an internet connection for free. The results show that basic internet access is not provided by every LTCF; however, Switzerland's ICT infrastructure and internet use of people aged 65 years and older are more equipped than other countries where individual residents need to pay for such services (33). Nevertheless, the results also show the degree of missing infrastructure for widespread telemedicine solutions within LTCFs (e.g., free internet access or mobile devices to use telemedicine apps privately).

The above-mentioned study (32) also asked the LTCF managers if they already used telemedicine (teleconsultation of doctors and/or health practitioners) within their facilities; only 3.9% of all 466 participating LTCFs used telemedicine. When asked if the managers evaluated telemedicine as useful for their facilities, 21.7% found it "rather useful" and 14.5% found it "very useful"; the rest (63.8%) found it rather not so useful or very non-useful. For this study, the authors did not have information related to the barriers or attitudes toward telemedicine; nevertheless, the authors demonstrated that telemedicine solutions were available in the minority among LTCFs in Switzerland, with few managers (36.2%) finding telemedicine useful. Only 11.1% of the managers in this study (32) said they involved their residents in decision-making about purchasing new technology for the institution. This corroborates the assumption that LTCFs are contextual settings with potential elements of a self-contained institution (34) with modest participation of residents in the process of initiating new technology solutions such as telemedicine.

RECOMMENDATIONS

Based on the presented data, we recommend (1) education and training of staff and residents, (2) a solid telemedicine infrastructure, and (3) a system that promotes and integrates telemedicine in daily workflows within LTCFs.

First, given the rapid expansion of telemedicine, it is paramount to educate both LTCF staff and residents about how to use telemedicine, which could be useful in their daily lives during and beyond the current pandemic. The LTCF staffs are the coordinators and attend consultations with the patient; therefore, they are very important to include in all learning settings of telemedicine. It would be helpful to offer support and training to these people to increase their digital literacy skills. Establishing a workforce within LTCF environments with telemedicine competencies is important; this has not yet been anchored in education or evidence-based training (35). Learning new technical skills can even foster a certain sense of competence and autonomy (36) within older adults that can encourage the efficient use of other digital interventions. The special learning needs and cognitive resources of older adults need to be considered in these educational services, with attention paid to things such as the tempo of the learning session and the technological skill background of the older participants (37). These learning tools can be generally provided by LTCFs with the help of technical and management experts in telemedicine.

Second, besides the user side of telemedicine, the results from Switzerland reveal that LTCFs before, during, and probably

beyond the COVID-19 pandemic have low levels of telemedicine infrastructure. This situation has pointed out that although telemedicine solutions would be ideal for medical treatments and consultations during physical distancing; however LTCFs are not yet ready for this task. It is critical to motivate developers and professional users (e.g., researchers, medical practitioners, and companies within the health sector) of telemedicine to take a closer look at how different designs and content can be tailored in a way that encourages trust and facilitates use among older people and LTCF staff. All stakeholders are encouraged to address these challenges and collaborate to promote the safe and evidence-based use of telemedicine during the current pandemic and future outbreaks (38, 39). The integration of end-users into workflows and the design process increases the usage and effectiveness of interventions, particularly as a partner in community-based participatory research in advance of developing a new digital intervention (40, 41). During any intervention, a real-time, support hotline, and contact partner can be used to assist the older participants when needed.

Third, telemedicine should not be system only used during a pandemic, but rather a routine method of providing services in our health system (31, 38, 42), and especially in LTCFs. We propose the following hurdles need to be overcome: (a) stable and high-performance internet access in all areas (cities or rural areas), (b) computers or mobile devices and software tools capable of engaging in telemedicine, (c) technical and software skills and skills in managing telemedicine processes among all stakeholders (e.g., residents, LTCF staff, doctors, medical staff), (d) willingness of all stakeholders to practice telemedicine, (e) interoperable communication systems and systems of exchange of health-related information and data, (f) availability of telemedicine support for staff or time for staff to do this within the daily business of care duties, (g) guidelines regarding the appropriate use of telemedicine, and (h) clinical and economical evidence from longitudinal studies within LTCF to support the effectiveness of the telemedicine services. Also, user focused studies are needed to better understand practical experiences from the perspective of resident and staff; and factors influencing uptake and acceptance in the health system.

Telehealth can be considered a "disruptive innovation process" by implying changing the way we provide service delivery. The importance of managing this change process well cannot be overstated by including all of the stakeholders associated with successful telehealth are accounted for. One way to further the "digital connection during physical distancing" idea would be to not limit communication applications such as chatting or video-calling to doctors, but to use such tools also for connecting with friends and relatives. The pandemic has fostered the potential of those social tools for digital connections within LTCFs (43), so why not also use those tools to help residents connect with the world beyond LTCFs? Current projects (44) use Skype, for example, for telemedicine under control for privacy and security requirements. However, also potential socio-economic inequalities in the use of telemedicine (45–47) or technology in general among older adults should be taken into account (15, 19, 33). Telemedicine enables cost savings (e.g., no transfer to the doctors' office), but also causes additional costs for older people (economical cost and acquired technical skills). Furthermore, potential barriers for digital excluded groups, such as older adults in LTCF, should be discussed and existing policy opinions should be considered when integrating telemedicine in everyday practice (48).

CONCLUSIONS

The current pandemic highlights the challenges of providing LTCF residents with timely medical treatment during physical distancing and the potential of routinely using telemedicine in clinical care. Although the benefits of telemedicine have been widely reported, its routine use and its systematic evaluation for residents in LTCFs has been relatively limited. Integrating telemedicine is reliant on many complex and interrelated factors which must be addressed for successful adoption. Aside from the technical requirements, it is just as important to ensure that a supportive infrastructure are in place to support telemedicine services, systems are interoperable between service providers and recipients of care, staff are trained in its use, procedures are in place to ensure the safe and effective delivery of care, responsibilities for telemedicine care are clearly articulated, and funding is available to support the effort. The current pandemic has reminded us that innovative models of care that include telemedicine can be helpful, but organizational readiness to adopt telemedicine needs urgent attention.

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All authors provided substantial contributions to this article from conception to final approval and share the same opinion.

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REFERENCES

1. Hwang T-J, Rabheru K, Peisah C, Reichman W, Ikeda M. Loneliness and social isolation during the COVID-19 pandemic. *Int Psychogeriatr*. (2020). doi: 10.1017/S1041610220000988. [Epub ahead of print].
2. Kivi M, Hansson I, Bjälkebring P. Up and about: older adults' wellbeing during the COVID-19 pandemic in a Swedish longitudinal study. *J Gerontol Ser B*. (2020). doi: 10.1093/geronb/gbaa084. [Epub ahead of print].
3. Comas-Herrera A, Zalakain J. *Mortality Associated With COVID-19 Outbreaks in Care Homes: Early International Evidence*. (2020) Available online at: https://ltccovid.org/wp-content/uploads/2020/05/Mortality-associated-with-COVID-3-May-final-5.pdf (accessed May 11, 2020).
4. CDC. *Older Adults*. (2020) Available online at: https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/older-adults.html (accessed April 23, 2020).

5. Hollander JE, Carr BG. Virtually perfect? Telemedicine for Covid-19. *N Engl J Med*. (2020) 382:1679–81. doi: 10.1056/NEJMp2003539
6. Lurie N, Carr BG. The role of telehealth in the medical response to disasters. *JAMA Intern Med*. (2018) 178:745. doi: 10.1001/jamainternmed.2018.1314
7. Tozzi AE, Gesualdo F, D'Ambrosio A, Pandolfi E, Agricola E, Lopalco P. Can digital tools be used for improving immunization programs? *Front Public Health*. (2016) 4:36. doi: 10.3389/fpubh.2016.00036
8. Woodall T, Ramage M, LaBruyere JT, McLean W, Tak CR. Telemedicine services during COVID-19: considerations for medically underserved populations. *J Rural Health*. (2020). doi: 10.1111/jrh.12466. [Epub ahead of print].
9. Batsis JA, DiMilia PR, Seo LM, Fortuna KL, Kennedy MA, Blunt HB, et al. Effectiveness of ambulatory telemedicine care in older adults: a systematic review. *J Am Geriatr Soc*. (2019) 67:1737–49. doi: 10.1111/jgs.15959
10. Seifert A, Cotten SR, Xie B. A double burden of exclusion? Digital and social exclusion of older adults in times of COVID-19. *J Gerontol Soc Sci*. (2020). doi: 10.1093/geronb/gbaa098. [Epub ahead of print].
11. Zhai Y. A call for addressing barriers to telemedicine: health disparities during the COVID-19 pandemic. *Psychother Psychosom*. (2020). doi: 10.1159/000509000. [Epub ahead of print].
12. Zhou X, Snoswell CL, Harding LE, Bambling M, Edirippulige S, Bai X, et al. The role of telehealth in reducing the mental health burden from COVID-19. *Telemed E-Health*. (2020) 26:377–9. doi: 10.1089/tmj.2020.0068
13. Wosik J, Fudim M, Cameron B, Gellad ZF, Cho A, Phinney D, et al. Telehealth transformation: COVID-19 and the rise of virtual care. *J Am Med Inform Assoc*. (2020) 27:957–62. doi: 10.1093/jamia/ocaa067
14. Lam K, Lu AD, Shi Y, Covinsky KE. Assessing telemedicine unreadiness among older adults in the United States during the COVID-19 pandemic. *JAMA Intern Med*. (2020). doi: 10.1001/jamainternmed.2020.2671. [Epub ahead of print].
15. Seifert A, Rössel J. "Digital participation." In: Gu D, Dupre ME, editors. *Encyclopedia of Gerontology and Population Aging*. Cham: Springer International Publishing (2020). p. 1–5.
16. Robinson L, Schulz J, Khilnani A, Ono H, Cotten SR, McClain N, et al. Digital inequalities in time of pandemic: COVID-19 exposure risk profiles and new forms of vulnerability. *First Monday*. (2020). doi: 10.5210/fm.v25i7.10845. [Epub ahead of print].
17. Xie B, Charness N, Fingerman K, Kaye J, Kim MT, Khurshid A. When going digital becomes a necessity: ensuring older adults' needs for information, services, and social inclusion during COVID-19. *J Aging Soc Policy*. (2020). doi: 10.1080/08959420.2020.1771237. [Epub ahead of print].
18. Beaunoyer E, Dupéré S, Guitton MJ. COVID-19 and digital inequalities: reciprocal impacts and mitigation strategies. *Comput Hum Behav*. (2020) 111:106424. doi: 10.1016/j.chb.2020.106424
19. Seifert A, Cotten SR. In care and digitally savvy? Modern ICT use in long-term care institutions. *Educ Gerontol*. (2020) 46:473–85. doi: 10.1080/03601277.2020.1776911
20. Seifert A, Doh M, Wahl H-W. They also do it: internet use by older adults living in residential care facilities. *Educ Gerontol*. (2017) 43:451–61. doi: 10.1080/03601277.2017.1326224
21. Berkowsky RW, Rikard RV, Cotten SR. "Signing off: predicting discontinued ICT usage among older adults in assisted and independent living." In: Zhou J, Salvendy J, editors. *Human Aspects of IT for the Aged Population. Design for Everyday Life*. Cham: Springer International Publishing (2015). p. 389–98.
22. Schlomann A, Seifert A, Zank S, Rietz C. Assistive technology and mobile ICT usage among oldest-old cohorts: comparison of the oldest-old in private homes and in long-term care facilities. *Res Aging*. (2020) 42:163–73. doi: 10.1177/0164027520911286
23. Francis J, Rikard RV, Cotten SR, Kadylak T. Does ICT Use matter? How information and communication technology use affects perceived mattering among a predominantly female sample of older adults residing in retirement communities. *Inf Commun Soc*. (2019) 22:1281–94. doi: 10.1080/1369118X.2017.1417459
24. Rikard RV, Berkowsky RW, Cotten SR. Discontinued information and communication technology usage among older adults in continuing care retirement communities in the United States. *Gerontology*. (2018) 64:188–200. doi: 10.1159/000482017
25. Moyle W, Jones C, Murfield J, Dwan T, Ownsworth T. "We don't even have Wi-Fi": a descriptive study exploring current use and availability of communication technologies in residential aged care. *Contemp Nurse*. (2018) 54:35–43. doi: 10.1080/10376178.2017.1411203
26. Powell KR, Alexander GL, Madsen R, Deroche C. A national assessment of access to technology among nursing home residents: a secondary analysis. *JMIR Aging*. (2019) 2:e11449. doi: 10.2196/11449
27. Konttila J, Siira H, Kyngäs H, Lahtinen M, Elo S, Kääriäinen M, et al. Healthcare professionals' competence in digitalisation: a systematic review. *J Clin Nurs*. (2019) 28:745–61. doi: 10.1111/jocn.14710
28. O'Sullivan JL, Gellert P, Hesse B, Jordan L-M, Möller S, Voigt-Antons J-N, et al. Exploring attitudes of healthcare professionals towards ICT-based interventions for nursing home residents with dementia: a mixed-methods approach. *Contemp Nurse*. (2018) 54:13–25. doi: 10.1080/10376178.2017.1421087
29. Edirippulige S, Martin-Khan M, Beattie E, Smith AC, Gray LC. A systematic review of telemedicine services for residents in long term care facilities. *J Telemed Telecare*. (2013) 19:127–32. doi: 10.1177/1357633X13483256
30. Lyketsos CG, Roques C, Hovanec L, Jones BN. Telemedicine use and the reduction of psychiatric admissions from a long-term care facility. *J Geriatr Psychiatry Neurol*. (2001) 14:76–9. doi: 10.1177/089198870101400206
31. Bashshur R, Doarn CR, Frenk JM, Kvedar JC, Woolliscroft JO. Telemedicine and the COVID-19 pandemic, lessons for the future. *Telemed J E Health*. (2020) 26:571–3. doi: 10.1089/tmj.2020.29040.rb
32. Seifert A, Ackermann T. *Digitalisierung in Institutionen für Menschen im Alter*. Zürich: Zentrum für Gerontologie (2020).
33. König R, Seifert A, Doh M. Internet use among older Europeans: an analysis based on SHARE data. *Univers Access Inf Soc*. (2018) 17:621–33. doi: 10.1007/s10209-018-0609-5
34. Goffman E. *Asylums: Essays on the Social Situation of Mental Patients and Other Inmates*. New York, NY: Anchor Books (1961).
35. Edirippulige S, Brooks P, Carati C, Wade VA, Smith AC, Wickramasinghe S, et al. It's important, but not important enough: eHealth as a curriculum priority in medical education in Australia. *J Telemed Telecare*. (2018) 24:697–702. doi: 10.1177/1357633X18793282
36. Nimrod G. The benefits of and constraints to participation in seniors' online communities. *Leis Stud*. (2014) 33:247–66. doi: 10.1080/02614367.2012.697697
37. Czaja SJ, Boot WR, Charness N, Rogers WA. *Designing for Older Adults: Principles and Creative Human Factors Approaches*. Boca Raton, FL: CRC Press (2019).
38. Ohannessian R, Duong TA, Odone A. Global telemedicine implementation and integration within health systems to fight the COVID-19 pandemic: a call to action. *JMIR Public Health Surveill*. (2020). doi: 10.2196/18810. [Epub ahead of print].
39. Armfield NR, Edirippulige SK, Bradford N, Smith AC. Telemedicine — is the cart being put before the horse? *Med J Aust*. (2014) 200:530–3. doi: 10.5694/mja13.11101
40. de Beurs D, van Bruinessen I, Noordman J, Friele R, van Dulmen S. Active involvement of end users when developing web-based mental health interventions. *Front Psychiatry*. (2017) 8:72. doi: 10.3389/fpsyt.2017.00072
41. Clemensen J, Rothmann MJ, Smith AC, Caffery LJ, Danbjorg DB. Participatory design methods in telemedicine research. *J Telemed Telecare*. (2017) 23:780–5. doi: 10.1177/1357633X16686747
42. Smith AC, Thomas E, Snoswell CL, Haydon H, Mehrotra A, Clemensen J, et al. Telehealth for global emergencies: implications for coronavirus disease 2019 (COVID-19). *J Telemed Telecare*. (2020) 26:309–13. doi: 10.1177/1357633X20916567
43. Marston HR, Musselwhite C, Hadley R. COVID-19 vs social isolation: the impact technology can have on communities, social connections and citizens. *British Society of Gerontology. Ageing Issues*. (2020) Available at: https://ageingissues.wordpress.com/2020/03/18/covid-19-vs-social-isolation-the-impact-technology-can-have-on-communities-social-connections-and-citizens/ (accessed June 2, 2020).
44. Armfield NR, Gray LC, Smith AC. Clinical use of Skype: a review of the evidence base. *J Telemed Telecare*. (2012) 18:125–7. doi: 10.1258/jtt.2012.SFT101

45. Delgoshaei B, Mobinizadeh M, Mojdekar R, Afzal E, Arabloo J, Mohamadi E. Telemedicine: a systematic review of economic evaluations. *Med J Islam Republic Iran*. (2017) 31:754–61. doi: 10.14196/mjiri.31.113
46. Wade VA, Karnon J, Elshaug AG, Hiller JE. A systematic review of economic analyses of telehealth services using real time video communication. *BMC Health Serv Res*. (2010) 10:233. doi: 10.1186/1472-6963-10-233
47. Eze ND, Mateus C, Cravo Oliveira Hashiguchi T. Telemedicine in the OECD: an umbrella review of clinical and cost-effectiveness, patient experience and implementation. *PLoS ONE*. (2020) 15:e0237585. doi: 10.1371/journal.pone.0237585
48. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system REsilience PROGRAM (REPROGRAM) International Consortium (Part 2). *Front Public Health*. (2020) 8:410. doi: 10.3389/fpubh.2020.00410

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Designing Futuristic Telemedicine Using Artificial Intelligence and Robotics in the COVID-19 Era

Sonu Bhaskar[1,2*], *Sian Bradley*[1,3], *Sateesh Sakhamuri*[1,4], *Sebastian Moguilner*[1,5], *Vijay Kumar Chattu*[1,6], *Shawna Pandya*[1,7], *Starr Schroeder*[1,8], *Daniel Ray*[1,9] and *Maciej Banach*[1,10,11]

[1] *Pandemic Health System REsilience PROGRAM (REPROGRAM) Consortium, REPROGRAM Telemedicine Study Group, Sydney, NSW, Australia,* [2] *Neurovascular Imaging Laboratory & NSW Brain Clot Bank, Department of Neurology, Liverpool Hospital and South Western Sydney Local Health District, Ingham Institute for Applied Medical Research, The University of New South Wales, Sydney, NSW, Australia,* [3] *The University of New South Wales (UNSW) Medicine Sydney, South West Sydney Clinical School, Sydney, NSW, Australia,* [4] *The University of the West Indies, St. Augustine, Trinidad and Tobago,* [5] *Global Brain Health Institute, Trinity College Dublin, Dublin, Ireland,* [6] *Department of Medicine, St. Michael's Hospital, University of Toronto, Toronto, ON, Canada,* [7] *Alberta Health Services and Project PoSSUM, University of Alberta, Edmonton, AB, Canada,* [8] *Penn Medicine Lancaster General Hospital and Project PoSSUM, Lancaster, PA, United States,* [9] *Farr Institute of Health Informatics, University College London (UCL) & NHS Foundation Trust, Birmingham, United Kingdom,* [10] *Polish Mother's Memorial Hospital Research Institute (PMMHRI) in Lodz, Cardiovascular Research Centre, University of Zielona Gora, Zielona Gora, Poland,* [11] *Department of Hypertension, Medical University of Lodz, Łódź, Poland*

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***Correspondence:**
Sonu Bhaskar
Sonu.Bhaskar@health.nsw.gov.au

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Technological innovations such as artificial intelligence and robotics may be of potential use in telemedicine and in building capacity to respond to future pandemics beyond the current COVID-19 era. Our international consortium of interdisciplinary experts in clinical medicine, health policy, and telemedicine have identified gaps in uptake and implementation of telemedicine or telehealth across geographics and medical specialties. This paper discusses various artificial intelligence and robotics-assisted telemedicine or telehealth applications during COVID-19 and presents an alternative artificial intelligence assisted telemedicine framework to accelerate the rapid deployment of telemedicine and improve access to quality and cost-effective healthcare. We postulate that the artificial intelligence assisted telemedicine framework would be indispensable in creating futuristic and resilient health systems that can support communities amidst pandemics.

Keywords: telehealth, digital medicine, pandemic (COVID-19), robotics, telemedicine, artificial intelligence, coronavirus disease 2019 (COVID-19)

INTRODUCTION

Telemedicine or telehealth is the use of medical information to improve patient's health (1, 2). Reorganization in healthcare delivery, financing, and advancement in electronic health records and clinical decision support systems can accelerate the telehealth adoption into healthcare delivery (2). In this context, artificial intelligence (AI) and robotic technologies can play an important role in the use and delivery of telemedicine during coronavirus disease (COVID-19) and the post-pandemic world (3–10). Our previous two reports have identified gaps in telemedicine across geographics and medical specialties (11, 12). The current paper is a call for the integration of AI, robotics, and telemedicine with an organizational framework powered by AI to accelerate healthcare delivery and improve access to healthcare in the context of public health preparedness and response during outbreaks or public health emergencies such as COVID-19.

ARTIFICIAL INTELLIGENCE ASSISTED TELEMEDICINE

Diagnosis is a multidisciplinary process that may involve multimodal testing such as clinical, imaging, blood, and genetic markers. Moreover, discipline-specific testing such as neuropsychological tests may be needed, for example, to obtain comprehensive mental health assessments (13). In a telemedicine framework, some of these testing may be unavailable, while others may be cost-prohibitive. To address this complex multivariate problem in finding an optimal diagnostic protocol, innovative data-driven artificial intelligence (AI) algorithms may offer a solution by applying machine learning to large datasets of disease populations (14, 15). These models can learn directly from the data without any prior statistical modeling, thus producing more objective results while focusing on prediction generalizability for diagnostic purposes on diverse populations. Since the COVID-19 outbreak, international efforts toward COVID-19 forecasting, prevention and treatment are underway using data-driven tools and pooled datasets (16). Moreover, the ML model features an important analysis that enables the search for more cost-effective protocols (17). Unlike traditional statistical hypothesis testing, data-driven computational approaches can test for synergistic variable combinations and redundant feature elimination enabling more effective diagnosis under the specific constraints of telemedicine (18).

Analysis by Collier et al. found that the use of AI applications could result in ∼$150 billion in saved healthcare costs annually by 2026 in the United States (19). According to Wahl et al., the ubiquitous use of smartphones, combined with growing investments in supporting technologies (e.g., mHealth, electronic medical record (EMR), and cloud computing), provide ample opportunities to use AI applications to improve public health outcomes in low-income country settings (20). Rapidly increased usage of electronic gadgets accelerates digital shifts in healthcare that appear to become essential in sharing information between and within medical workers and patients (21).

AI exhibits clear advantages over humans in analytical reasoning and problem solving (especially when large amounts of data are involved) and can effectively address the limitations of human function (22). However, the use of AI in healthcare must consider or mitigate the potential loss of vital physician skills if AI is over-utilized (17). Furthermore, rigid algorithm protocols and decision-making trees are subject to the consequences of the inability of AI to fully take in and interpret contextual information or delineate between relevant vs. non-relevant informational input even when employing deep machine learning (23). Contingencies are the norm in healthcare, and the human skill required to navigate and manage this off-nominal, or unpredictable situations must be carefully weighed against the advantages of using AI technology (23–28). User interface and data input methods are critical as voice recognition and interpretation is a major challenge of AI utilization (29). Generalized challenges to utilizing AI in healthcare are created by the fact that many cares and treatment decisions, especially in emergent and time-restricted scenarios hinge on human thought processes that occur in the subconscious, such as intuition, insight, subjective evaluation, and the analyzation of ambiguous or qualitative data (30). Jarrahi illustrates the benefit of the symbiotic use of AI combined with a human in the loop by showing the statistically significant reduction of error (85%) in detecting cancer in images of lymph nodes when compared to AI or human interpretation alone (30).

Telemedicine has provided a critical patient continuity pathway in times of disruption in health service during COVID-19 (10–12). This also helps protect healthcare facilities and minimize risks to health workers during pandemics, which/who are increasingly under pressure (31–33). Telemedicine has the potential to minimize the economic impact on society and healthcare services. Quarantined doctors can provide these services in medical institutions with remote access or care via telecommunications directly to the consumer, freeing other doctors to provide immediate assistance to more needy patients. Teleconsultations allow doctors to evaluate patients, detect signs of infection, and quickly and easily document patients who might be at higher risk of illness (34). Telemedicine solutions work promptly, filling out insurance documents, which allows doctors to devote more time to treating patients. Clinics are expanding their telehealth services to screen patients for COVID-19, which is critical to identifying patients and speeding up medical care, as well as limiting public exposure (11, 32). Bundling of various specialties such as teleradiology, tele-oncology, and telepathology is another area of crucial consideration to facilitate comprehensive management (35).

Further upstream in the telemedical framework, it is important to consider the integration of educational models for physicians and trainees, and particularly how these technologies may address the issues of connecting distributed learners (particularly in the era of a pandemic) (36), and providing high-quality educating, training, and just-in-time training, in a way that is trusted, safe, and replicates the quality of "in-person" training, particularly when it comes to surgical procedures (37, 38). Immersive technologies such as virtual reality and augmented reality could enhance capabilities for collaboration, both amongst learners and physicians in practice (39). Lastly, as has been mentioned elsewhere in this paper, immersive and telemedical technologies, whether used for consultations, treatments, and diagnostics, or education, must be resilient and capable of maintaining at least some degree of functionality even in the absence of internet or network connectivity (40). This is relevant to areas where broadband internet access is poor which limits the effective implementation of these technologies (41).

ROBOTICS ASSISTED TELEMEDICINE

Robotics is a promising cutting-edge tool in telemedicine that has potential applications in transforming physical exam and clinical care, as well as monitoring patients in remote conditions (42, 43). Such experience with the Ebola outbreak and with the COVID-19 pandemic has revealed a wide range of robotic uses and telemedicine options (43, 44). Robotics can be used in outbreaks of infections to minimize further exposure (45, 46):

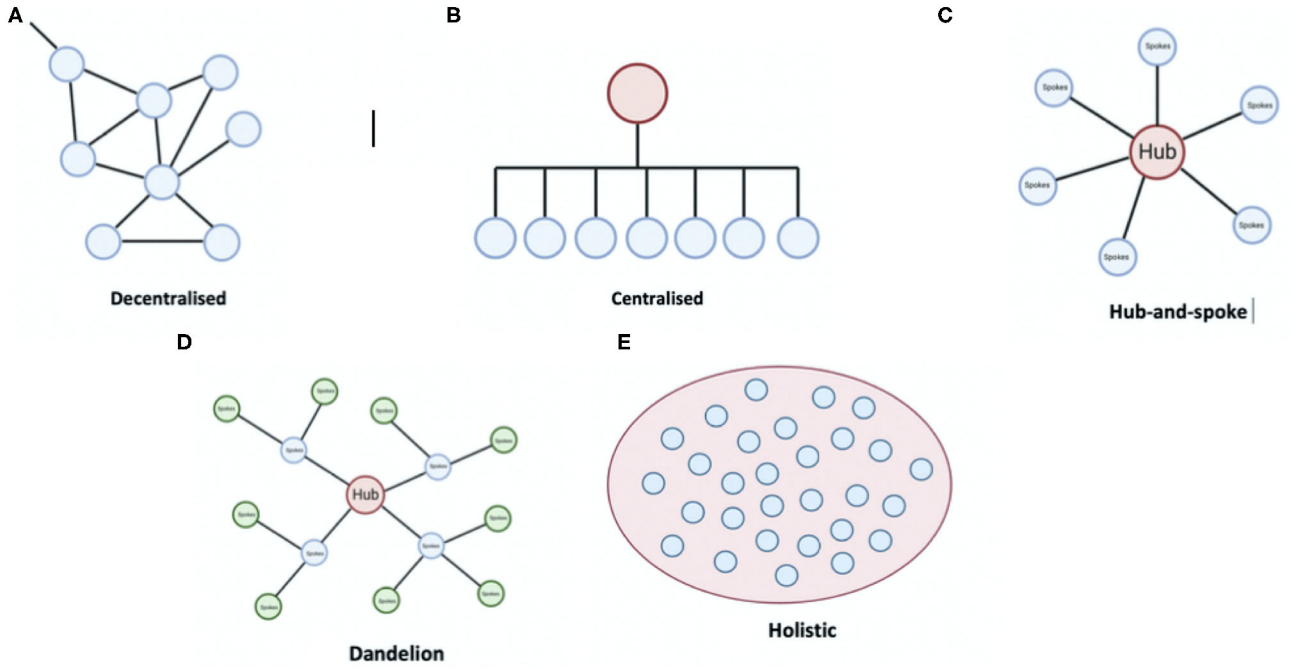

FIGURE 1 | Traditional organizational frameworks such as **(A)** Decentralized, **(B)** Centralized, **(C)** Hub-and-spoke, **(D)** Dandelion, and **(E)** Holistic are shown.

for disinfection, delivery of drugs and food, measuring vital signs, facilitating border control, and automatic disinfection (43). Telepresence robots allow for two-way communication and can be remotely controlled to provide support to those in isolation by connecting patients with family and physicians (35). Exposure to COVID-19 may stimulate further robotics research to address the risk of infectious diseases (42). Facilitating the integration of engineering, video technology, and infectious diseases specialists with government funding can have a notable impact on preventing future pandemics. A Smart Field Hospital trial in Wuhan, China, used robots to minimize COVID-19 exposure to patients and healthcare workers as robots and internet of things (IoT) devices provided medical services in the facility (47). The adoption of robots could be explored in infectious disease and crisis settings as a means to potentially improve health systems capacity and preparedness (47).

The Society of European Robotic Gynecological Surgery has released guidelines for robot-assisted surgery (RAS) and promoted the use of RAS over conventional laparoscopic and open surgery in managing infection risk (48). Where RAS is not possible, conventional laparoscopic is preferred over open surgery due to the reduced amount of physicians and PPE required, aerosol and bodily fluid risk, and shortened hospital stay (48, 49). The European Association of Urology similarly released COVID-19 guidelines, in which they pressed the need to manage smoke dispersion in robotic or laparoscopic surgery through the use of lowest intra-abdominal pressure and management of flow systems (50).

Potential issues associated with robotics-assisted telemedicine, include precision and interaction issues due to distance between patient and operator, network issues, and communication issues (49). Robot-assisted surgery has the potential to reduce COVID-19 exposure risk to medical professionals (51).

TELEMEDICINE ORGANIZATIONAL FRAMEWORKS

Various traditional organizational frameworks are illustrated in **Figure 1**. One example of a traditional organization is the hub-and-spoke framework for stroke reperfusion therapy delivery (52), which is based on a framework of conventional and hierarchical positioning. It involves a centralized hub, which serves as a point of contact and instruction to several spoke sites that deliver care (53). This structure is suitable for the set-up and integration of telehealth networks but ultimately slows decision-making, depresses innovation, makes it difficult for spokes to communicate, and not everybody in the spoke has the capability of the hub (54). Due to cost-benefit and infrastructural reasons, as well as a shortage of neuro-interventionalists, not every spoke will have endovascular therapy capabilities. Additionally, barriers in access to health systems, applicable to culturally and linguistically diverse communities (CALD) as well as those from marginalized backgrounds or low resourced settings, merit special consideration (55, 56).

Centralized systems require strong leadership, otherwise, issues such as lack of efficiency, productivity, and physician well-being may develop (57). Decentralized systems can slow down the speed of uptake and pose inefficiency. Multiple hub-and-spokes are another framework that can be leveraged (58), e.g.,

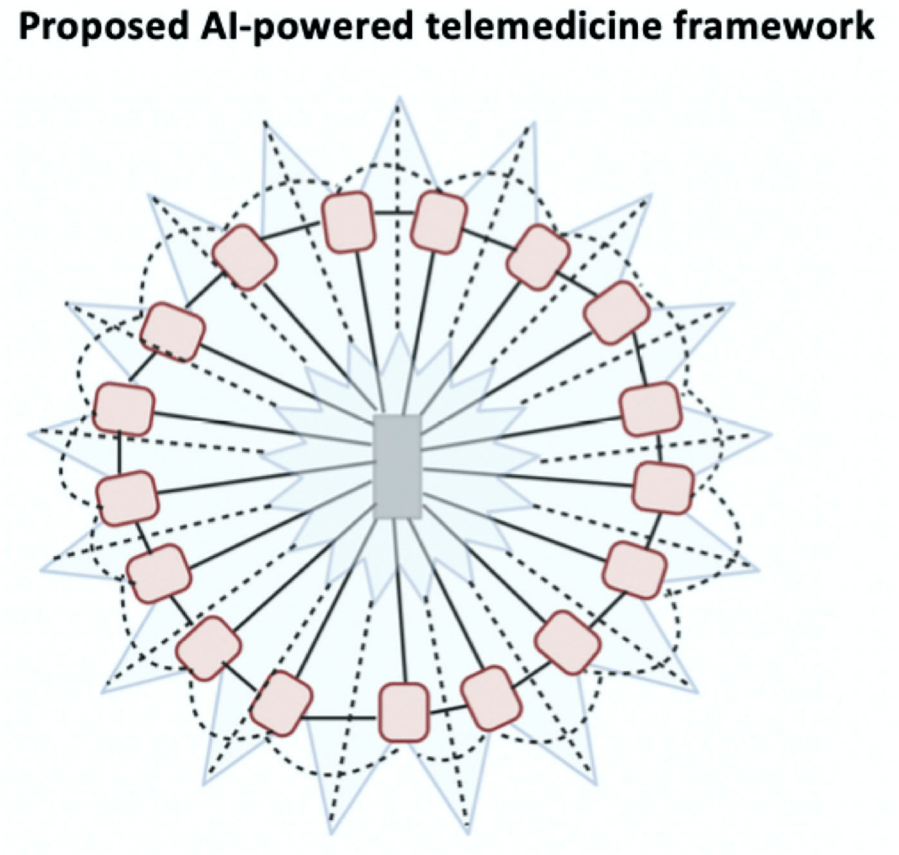

FIGURE 2 | The proposed artificial intelligence assisted framework for telemedicine. This system centers around artificial intelligence (AI) engine that looks within the network to find the optimal resources within the geographical constraints and route incoming calls to the appropriate node (affiliated healthcare provider/facility). This self-evolving and innovative approach processing system would potentially allow increased telemedicine penetration while reducing the inefficiencies of the top-down or conventional organizational frameworks.

in Africa, a capital city can have a hub overseeing the local state governments, which could further branch out. There also exists a holistic model, in which there is no hierarchy (59). Each element in the holistic structure is guided by the overarching vision of the organization.

DISCUSSION

Telemedicine offers a new modality of delivering medical & allied health services and communicating with patients (11). The current COVID-19 pandemic has catalyzed the uptake of telemedicine (12, 60). However, there are challenges concerning its geographical penetration, organizational structures, and infrastructure-related issues (12, 41). The consortium has outlined gaps in current telehealth approaches (11), including challenges to telemedicine implementation across geographics (12) and reliance on outdated organizational frameworks or operational structures discussed in the current report.

We propose a novel AI-powered staged-wise telemedicine organizational framework (61), which can potentially overcome the challenges associated with traditional organizational structures (**Figure 2**). Hub-and-spoke can be used as a foundational set-up to trigger the quick adoption of technology initially. However, after an initial period, once such a structure begins to stagnate and is no longer effective in skilling-up, a new organizational framework will replace the foundational model. The replacing model will consider leadership, technological, and organizational structure competence (61). This will involve a move toward performance and competency-based systems (62). For example, when an acute stroke call is made, an AI system will automatically find the best site of care depending on several variables, distance, availability of resources, clinicians' availability, and time constraints. This will focus on linking the patient to the best provider, thereby removing any elements of bureaucracy. An independent governance and ethical framework are necessary for oversight over the AI performance and any ethical issues (63, 64). An AI-powered system should prioritize the collective good and performance of the organization based on evidence-based management principles (65). It will be utilized to form linkages between providers. For instance, in the event of a cardiac emergency, the system could use the existing information on the patient to find the best teams to manage the patient.

Links between a cardiologist and cardiac surgeon will be made so that they can communicate quickly. This involves role-based linkage based on questions such as who is available quickly, who is available in the region, and whether the practitioner agrees to treat such patients, rather than subjective person-to-person linkage. Ultimately, however, such an autonomous framework must also be able to assign responsibility in case of oversights. Hub-and-spoke systems allow teams to compete with each other and to curry favor from management. The proposed AI-assisted telemedicine organizational framework is focused on role-competence and linkages, rather than individuals or teams. We anticipate this would foster regular and continuous collaboration. Powered by big data and advanced data analytics dashboard, AI-powered systems can be insightful because they generate information about resource utilization in different regions, providing recommendations on system reorganization and clinician mobilization in a COVID-19 pandemic situation. This involves scoping the landscape and realigning across multiple levels to embed that particular intervention within the health systems, thereby promoting rapid research and innovation translation as well as integrating contributions based on local needs. Such a framework would imbibe resilience, innovation-driven technology, and scaled intelligence to enable systems to evolve and be responsive to local and emergent needs such as during an outbreak. COVID-19 has led to a sharp increase in the demand for telemedicine services (5, 34). It also has an impact on telemedicine providers, a sector that is facing unprecedented demand, which by some estimates has grown by 150% or more (66). For telemedicine to expand across geographics, it is necessary to account for geographical variations, cultural factors, and involvement of local stakeholders (12).

CONCLUSION

To summarize, AI and robotics could play an important role in providing telemedicine services during an outbreak or public health emergency while limiting exposure to healthcare workers and health systems (14, 42, 43). The AI-assisted telemedicine framework proposed by the current consortium could be an enabler in improving telemedicine access and spread across medical specialties and geography. An international collaborative effort led by WHO, the current consortium, or similar organizations could pave a way to greater telemedicine penetration, especially to benefit the underprivileged and those living in the low-resourced settings (12).

AUTHOR'S NOTE

The COVID-19 pandemic is causing an unprecedented public health crisis impacting healthcare systems, healthcare workers, and communities. The COVID-19 Pandemic Health System REsilience PROGRAM (REPROGRAM) consortium is formed to champion the safety of healthcare workers, policy development, and advocacy for global pandemic preparedness and action.

AUTHOR CONTRIBUTIONS

SBh devised the project, the main conceptual ideas, including the proposal for a new AI-powered telemedicine workflow, the proof outline, coordinated the writing, editing of the manuscript, and wrote the first draft of the manuscript. All authors discussed the results and recommendations and contributed to the final manuscript.

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REFERENCES

1. World Health Organization. *Transforming and Scaling up Health Professionals' Education and Training*. Geneva: World Health Organization (2013). Available online at: https://www.who.int/hrh/resources/transf_scaling_hpet/en/ (accessed September 14, 2020).
2. Tuckson RV, Edmunds M, Hodgkins ML. Telehealth. *N Engl J Med*. (2017) 377:1585–92. doi: 10.1056/NEJMsr1503323
3. Ye J. The role of health technology and informatics in a global public health emergency: practices and implications from the COVID-19 pandemic. *JMIR Med Inform*. (2020) 8:e19866. doi: 10.2196/19866
4. Agbehadji IE, Awuzie BO, Ngowi AB, Millham RC. Review of big data analytics, artificial intelligence and nature-inspired computing models towards accurate detection of COVID-19 pandemic cases and contact tracing. *Int J Environ Res Public Health*. (2020) 17:5330. doi: 10.3390/ijerph17155330
5. Ohannessian R, Duong TA, Odone A. Global telemedicine implementation and integration within health systems to fight the COVID-19 pandemic: a call to action. *JMIR Public Health Surveill*. (2020) 6:e18810. doi: 10.2196/18810
6. Mahmood S, Hasan K, Colder Carras M, Labrique A. Global preparedness against COVID-19: we must leverage the power of digital health. *JMIR Public Health Surveill*. (2020) 6:e18980. doi: 10.2196/18980
7. Uohara MY, Weinstein JN, Rhew DC. The essential role of technology in the public health battle against COVID-19. *Popul Health Manag*. (2020) 23:361–7. doi: 10.1089/pop.2020.0187
8. Badawy SM, Radovic A. Digital approaches to remote pediatric health care delivery during the COVID-19 pandemic: existing evidence and a call for further research. *JMIR Pediatr Parent*. (2020) 3:e20049. doi: 10.2196/20049
9. Kricka LJ, Polevikov S, Park JY, Fortina P, Bernardini S, Satchkov D, et al. Artificial intelligence-powered search tools and resources in the fight against COVID-19. *EJIFCC*. (2020) 31:106–16.
10. Hollander JE, Carr BG. Virtually perfect? telemedicine for Covid-19. *N Engl J Med*. (2020) 382:1679–81. doi: 10.1056/NEJMp2003539
11. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system REsilience PROGRAM (REPROGRAM) international consortium (Part 2). *Front Public Health*. (2020) 8:410. doi: 10.3389/fpubh.2020.00410

12. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine across the globe - position paper from the COVID-19 pandemic health system resilience PROGRAM (REPROGRAM) international consortium (Part 1). *Front Public Health.* (2020) 8:556720. doi: 10.3389/fpubh.2020.556720
13. Huys QJM, Maia TV, Frank MJ. Computational psychiatry as a bridge from neuroscience to clinical applications. *Nat Neurosci.* (2016) 19:404–13. doi: 10.1038/nn.4238
14. Kuziemsky C, Maeder AJ, John O, Gogia SB, Basu A, Meher S, et al. Role of artificial intelligence within the telehealth domain. *Yearb Med Inform.* (2019) 28:35–40. doi: 10.1055/s-0039-1677897
15. Aractingi S, Pellacani G. Computational neural network in melanocytic lesions diagnosis: artificial intelligence to improve diagnosis in dermatology? *Eur J Dermatol.* (2019) 29:4–7. doi: 10.1684/ejd.2019.3538
16. Luo EM, Newman S, Amat M, Charpignon ML, Duralde ER, Jain S, et al. MIT COVID-19 datathon: data without boundaries. *BMJ Innovations.* (2020). doi: 10.1136/bmjinnov-2020-000492. [Epub ahead of print].
17. Ahuja AS. The impact of artificial intelligence in medicine on the future role of the physician. *PeerJ.* (2019) 7:e7702. doi: 10.7717/peerj.7702
18. Pacis DMM, Subido EDC, Bugtai NT. Trends in telemedicine utilizing artificial intelligence. *AIP Conf Proc.* (2018) 1933:040009. doi: 10.1063/1.5023979
19. Accenture. *Why Artificial Intelligence Is the Future of Growth.* (2020). Available online at: https://www.accenture.com/us-en/insight-artificial-intelligence-future-growth (accessed September 19, 2020).
20. Wahl B, Cossy-Gantner A, Germann S, Schwalbe NR. Artificial intelligence (AI) and global health: how can AI contribute to health in resource-poor settings? *BMJ Global Health.* (2018) 3:e000798. doi: 10.1136/bmjgh-2018-000798
21. Thierry JP. [The human resource: cornerstone of the digital transformation of the healthcare plan]. *Soins.* (2020) 65:46–7. doi: 10.1016/j.soin.2020.01.009
22. Huang M-H, Rust RT. Artificial intelligence in service. *J Serv Res.* (2018) 21:155–72. doi: 10.1177/1094670517752459
23. Heinrichs B, Eickhoff SB. Your evidence? Machine learning algorithms for medical diagnosis and prediction. *Hum Brain Mapp.* (2020) 41:1435–44. doi: 10.1002/hbm.24886
24. Grote T, Berens P. On the ethics of algorithmic decision-making in healthcare. *J Med Ethics.* (2020) 46:205–11. doi: 10.1136/medethics-2019-105586
25. London AJ. Artificial intelligence and black-box medical decisions: accuracy versus explainability. *Hastings Cent Rep.* (2019) 49:15–21. doi: 10.1002/hast.973
26. McDougall RJ. Computer knows best? The need for value-flexibility in medical AI. *J Med Ethics.* (2019) 45:156–60. doi: 10.1136/medethics-2018-105118
27. Sun W, Nasraoui O, Shafto P. Evolution and impact of bias in human and machine learning algorithm interaction. *PLoS ONE.* (2020) 15:e0235502. doi: 10.1371/journal.pone.0235502
28. Ash JS, Berg M, Coiera E. Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. *J Am Med Inform Assoc.* (2004) 11:104–12. doi: 10.1197/jamia.M1471
29. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. *Future Healthc J.* (2019) 6:94–8. doi: 10.7861/futurehosp.6-2-94
30. Jarrahi MH. Artificial intelligence and the future of work: human-AI symbiosis in organizational decision making. *Bus Horiz.* (2018) 61:577–86. doi: 10.1016/j.bushor.2018.03.007
31. Bhaskar S, Bradley S, Israeli-Korn S, Menon B, Chattu VK, Thomas P, et al. Chronic neurology in COVID-19 era: clinical considerations and recommendations from the REPROGRAM consortium. *Front Neurol.* (2020) 11:664. doi: 10.3389/fneur.2020.00664
32. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) settings: recommendations from the REPROGRAM consortium. *Front Cardiovasc Med.* (2020) 7:112. doi: 10.3389/fcvm.2020.00112
33. Bhaskar S, Sharma D, Walker AH, McDonald M, Huasen B, Haridas A, et al. Acute neurological care in the COVID-19 era: the pandemic health system REsilience PROGRAM (REPROGRAM) consortium pathway. *Front Neurol.* (2020) 11:579. doi: 10.3389/fneur.2020.00579
34. Sinha S, Kern LM, Gingras LF, Reshetnyak E, Tung J, Pelzman F, et al. implementation of video visits during COVID-19: lessons learned from a primary care practice in New York City. *Front Public Health.* (2020) 8:514. doi: 10.3389/fpubh.2020.00514
35. Bakas T, Sampsel D, Israel J, Chamnikar A, Ellard A, Clark JG, et al. Satisfaction and technology evaluation of a telehealth robotic program to optimize healthy independent living for older adults. *J Nurs Scholarsh.* (2018) 50:666–75. doi: 10.1111/jnu.12436
36. Lucey CR, Johnston SC. The transformational effects of COVID-19 on medical education. *JAMA.* (2020) 324:1033–4. doi: 10.1001/jama.2020.14136
37. Jumreornvong O, Yang E, Race J, Appel J. Telemedicine and medical education in the age of COVID-19. *Acad Med.* (2020). doi: 10.1097/ACM.0000000000003711. [Epub ahead of print].
38. Aron JA, Bulteel AJB, Clayman KA, Cornett JA, Filtz K, Heneghan L, et al. A role for telemedicine in medical education during the COVID-19 pandemic. *Acad Med.* (2020). doi: 10.1097/ACM.0000000000003572. [Epub ahead of print].
39. Bremner R, Gibbs A, Mitchell ARJ. The era of immersive health technology. *EMJ Innov.* (2020) 4:40–7.
40. Institute of Medicine (US) Committee on Assuring the Health of the Public in the 21st Century. *The Future of the Public's Health in the 21st Century*. Washington, DC: National Academies Press (2002). The Health Care Delivery System. Available online at: https://www.ncbi.nlm.nih.gov/books/NBK221227/ (accessed September 19, 2020).
41. Drake C, Zhang Y, Chaiyachati KH, Polsky D. The limitations of poor broadband internet access for telemedicine use in Rural America: an observational study. *Ann Intern Med.* (2019) 171:382–4. doi: 10.7326/M19-0283
42. Tavakoli M, Carriere J, Torabi A. Robotics, smart wearable technologies, and autonomous intelligent systems for healthcare during the COVID-19 pandemic: an analysis of the state of the art and future vision. *Adv Intell Syst.* (2020) 2:2000071. doi: 10.1002/aisy.202000071
43. Yang G-Z, Nelson JB, Murphy RR, Choset H, Christensen H, Collins HS, et al. Combating COVID-19—The role of robotics in managing public health and infectious diseases. *Sci Robot.* (2020) 5:eabb5589. doi: 10.1126/scirobotics.abb5589
44. Deng B. Robo-rescuers battle it out in disaster challenge. *Nature.* (2015) 519:14–5. doi: 10.1038/519014a
45. Kovach CR, Taneli Y, Neiman T, Dyer EM, Arzaga AJA, Kelber ST. Evaluation of an ultraviolet room disinfection protocol to decrease nursing home microbial burden, infection and hospitalization rates. *BMC Infect Dis.* (2017) 17:186. doi: 10.1186/s12879-017-2275-2
46. Yang G, Lv H, Zhang Z, Yang L, Deng J, You S, et al. Keep healthcare workers safe: application of teleoperated robot in isolation ward for COVID-19 prevention and control. *Chin J Mech Eng.* (2020) 33:47. doi: 10.1186/s10033-020-00464-0
47. Hornyak T. CNBC. *What America can learn from China's use of robots and telemedicine to combat the coronavirus.* (2020). Available online at: https://www.cnbc.com/2020/03/18/how-china-is-using-robots-and-telemedicine-to-combat-the-coronavirus.html (accessed September 14, 2020).
48. Kimmig R, Verheijen RHM, Rudnicki M. Robot assisted surgery during the COVID-19 pandemic, especially for gynecological cancer: a statement of the Society of European Robotic Gynaecological Surgery (SERGS). *J Gynecol Oncol.* (2020) 31:e59. doi: 10.3802/jgo.2020.31.e59
49. Avgousti S, Christoforou EG, Panayides AS, Voskarides S, Novales C, Nouaille L, et al. Medical telerobotic systems: current status and future trends. *BioMed Eng Online.* (2016) 15:96. doi: 10.1186/s12938-016-0217-7
50. Mottrie A. ERUS 2020. *ERUS (EAU Robotic Urology Section) guidelines during COVID-19 emergency.* (2020). Available online at: https://uroweb.org/wp-content/uploads/ERUS-guidelines-for-COVID-def.pdf (accessed 27 April 2020).
51. Samalavicius NE, Siaulys R, Janusonis V, Klimasauskiene V, Dulskas A. Use of 4 robotic arms performing Senhance® robotic surgery may reduce the risk of coronavirus infection to medical professionals during COVID-19. *Eur J Obstet Gynecol Reprod Biol.* (2020) 251:274–5. doi: 10.1016/j.ejogrb.2020.06.014

52. Demaerschalk BM, Boyd EL, Barrett KM, Gamble DM, Sonchik S, Comer MM, et al. Comparison of stroke outcomes of hub and spoke hospital treated patients in mayo clinic telestroke program. *J Stroke Cerebrovasc Dis.* (2018) 27:2940–2. doi: 10.1016/j.jstrokecerebrovasdis.2018.06.024
53. Subramanian S, Pamplin JC, Hravnak M, Hielsberg C, Riker R, Rincon F, et al. Tele-critical care: an update from the society of critical care medicine tele-ICU committee. *Crit Care Med.* (2020) 48:553–61. doi: 10.1097/CCM.0000000000004190
54. Elrod JK, Fortenberry JL. The hub-and-spoke organization design: an avenue for serving patients well. *BMC Health Serv Res.* (2017) 17:457. doi: 10.1186/s12913-017-2341-x
55. Bhaskar S, Thomas P, Cheng Q, Clement N, McDougall A, Hodgkinson S, et al. Trends in acute stroke presentations to an emergency department: implications for specific communities in accessing acute stroke care services. *Postgraduate Med J.* (2019) 95:258–64. doi: 10.1136/postgradmedj-2019-136413
56. Santana Baskar P, Cordato D, Wardman D, Bhaskar S. In-hospital acute stroke workflow in acute stroke – systems-based approaches. *Acta Neurol Scand.* (2020). doi: 10.1111/ane.13343. [Epub ahead of print].
57. Vantrappen H, Wirtz F. *Harvard Business Review. When to Decentralize Decision Making, and When Not To.* (2020). Available online at: https://hbr.org/2017/12/when-to-decentralize-decision-making-and-when-not-to (accessed September 14, 2020).
58. de Camargo RS, Miranda Jr G, Ferreira RPM, Luna HP. Multiple allocation hub-and-spoke network design under hub congestion. *Comp Operat Res.* (2009) 36:3097–106. doi: 10.1016/j.cor.2008.10.004
59. Doherty N, Champion D, Wang L. An holistic approach to understanding the changing nature of organisational structure. *IT People.* (2010) 23:116–35. doi: 10.1108/09593841011052138
60. Fisk M, Livingstone A, Pit SW. Telehealth in the context of COVID-19: changing perspectives in Australia, the United Kingdom, and the United States. *J Med Internet Res.* (2020) 22:e19264. doi: 10.2196/19264
61. Fountaine T, McCarthy B, Saleh T. *Harvard Business Review. Building the AI-Powered Organization.* (2019). Available online at: https://hbr.org/2019/07/building-the-ai-powered-organization (accessed September 19, 2020).
62. Korenková V, Závadský J, Lis M. Linking a performance management system and competencies: qualitative research. *Eng Manag Prod Serv.* (2019) 11:51–67. doi: 10.2478/emj-2019-0004
63. Anand M. Knowledge@Wharton. *Want Responsible AI? Think Business Outcomes" Knowledge@Wharton.* (2020). Available online at: https://knowledge.wharton.upenn.edu/article/want-responsible-ai-think-business-outcomes/ (accessed September 13, 2020).
64. Cobey C, Boillet J. EY. *How do You Teach AI the Value of Trust?* (2020). Available online at: https://www.ey.com/en_gl/digital/how-do-you-teach-ai-the-value-of-trust (accessed September 14, 2020).
65. West DM, Allen JR. Brookings. *How artificial intelligence is transforming the world.* (2018). Available online at: https://www.brookings.edu/research/how-artificial-intelligence-is-transforming-the-world/ (accessed September 14, 2020).
66. Frost & Sullivan 2020. *Telehealth—A Technology-Based Weapon in the War against the Coronavirus. Social Distancing Needs will Present Both Growth Opportunities and Challenges.* (2020). Available online at: https://go.frost.com/NA_PR_TH_MFernandez_K488_Telehealth_May20 (accessed September 19, 2020).

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At the Epicenter of COVID-19–the Tragic Failure of the Global Supply Chain for Medical Supplies

Sonu Bhaskar[1,2,3,4*], *Jeremy Tan*[1,4], *Marcel L. A. M. Bogers*[1,5,6,7], *Timo Minssen*[1,8,9], *Hishamuddin Badaruddin*[1,10], *Simon Israeli-Korn*[1,11,12] *and Henry Chesbrough*[1,7,13]

[1] *Pandemic Health System REsilience PROGRAM (REPROGRAM) Consortium, Innovation & Supply Chain Pandemic REPROGRAM Study Group, Sydney, NSW, Australia,* [2] *Department of Neurology & Neurophysiology, Liverpool Hospital and South Western Sydney Local Health District, Liverpool, NSW, Australia,* [3] *Neurovascular Imaging Laboratory, Clinical Sciences Stream and NSW Brain Clot Bank, Ingham Institute for Applied Medical Research, Sydney, NSW, Australia,* [4] *UNSW Medicine, South Western Sydney Clinical School, The University of New South Wales, Sydney, NSW, Australia,* [5] *Innovation, Technology Entrepreneurship and Marketing (ITEM) Group, Eindhoven University of Technology, Eindhoven, Netherlands,* [6] *Department of Food and Resource Economics, University of Copenhagen, Copenhagen, Denmark,* [7] *Garwood Center for Corporate Innovation, University of California, Berkeley, Berkeley, CA, United States,* [8] *Center for Advanced Studies in Biomedical Innovation Law, University of Copenhagen, Copenhagen, Denmark,* [9] *Faculty of Law, Lund University, Lund, Sweden,* [10] *College of Health and Human Development, Penn State University, State College, PA, United States,* [11] *Department of Neurology, Movement Disorders Institute, Sheba Medical Center, Ramat Gan, Israel,* [12] *Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel,* [13] *Maire Tecnimont Professor of Open Innovation, Luiss University, Rome, Italy*

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Edited by:
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Jinan University, China

****Correspondence:***
Sonu Bhaskar
sonu.bhaskar@health.nsw.gov.au

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The tragic failure of the global supply chain in the face of the current coronavirus outbreak has caused acute shortages of essential frontline medical devices and personal protective equipment, crushing fear among frontline health workers and causing fundamental concerns about the sustainability of the health system. Much more coordination, integration, and management of global supply chains will be needed to mitigate the impact of the pandemics. This article describes the pressing need to revisit the governance and resilience of the supply chains that amplified the crisis at pandemic scale. We propose a model that profiles critical stockpiles and improves production efficiency through new technologies such as advanced analytics and blockchain. A new governance system that supports intervention by public-health authorities during critical emergencies is central to our recommendation, both in the face of the current crisis and to be better prepared for potential future crises. These reinforcements offer the potential to minimize the compromise of our healthcare workers and health systems due to infection exposure and build capacity toward preparedness and action for a future outbreak.

Keywords: coronavirus disease 2019 (COVID-19), blockchain, open innovation, grand challenge, global supply chain, health policy, governance, personal protective equipments (PPEs)

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has inflicted severe shortages of acute healthcare materials, equipment, and resources such as personal protective equipments (PPEs), intensive care unit (ICU) beds, hand sanitisers, and mechanical ventilators (1–6). The World Health Organization (WHO) estimates global monthly consumption of 89 million masks, 76 million gloves and 1.6 million goggles (6). This is expected to increase, worsening pressures on health systems that are already under tremendous strain (7, 8). A public health emergency of this scale and scope is unprecedented in developed countries. The tragedy promises to challenge developing countries

even more severely in the coming weeks and months. The pervasiveness of COVID-19 globally has exposed that many countries are unprepared and ill-equipped to confront this viral mammoth (9).

There are several initiatives to address the acute need caused by this tragedy. For example, existing manufacturers have expedited the manufacturing process to meet the demands along with many other non-ventilator manufacturers such as Tesla, General Motors, Ford, Dyson and Rolls-Royce, exploring ways to repurpose their existing facilities to manufacture ventilators. Individual user initiatives are also responding to the lack of PPEs in many societies, with online instructions for making one's mask, and homemade recipes for hand sanitizer (3, 4, 10, 11). Despite current initiatives, much more coordination, integration, and management of global supply chains will be needed to mitigate the impact of the pandemics. Below, we first analyze the global supply chain, which has led to the current tragedy, we then propose a new strategy to overcome the pandemics shortfall and finally provide specific policy recommendations concerning regulation and governance of a new supply chain solution. In this paper, we call for a restructuring of governance over the global supply chain in the wake of the critical shortages arising during the COVID-19 pandemic.

KEY PROBLEMS WITH THE CURRENT GLOBAL SUPPLY CHAIN IN RESPONSE TO THE PANDEMIC

The global supply chain for critical medical equipment evolved after World War II to reflect multifaceted goals, including broad access, improving quality, and affordability. The large expenditures required to implement technological advances, together with the limited resources of tax-paying patients, has led over time to an intensification of the trade-offs between these goals. The lean supply chain was thus introduced in a bid to improve financial and operational performance. As of now, "lean" management has allowed for more efficient and effective logistical flow as well as improved customer satisfaction (12). But leanness has also led to adversity. Unfortunately, in reducing costs via labor and supply avenues, this has led to a reduction in medical stockpiles which act as "buffers" during crises like COVID-19 (13).

The dominant approach of leanness in managing global supply chains has been accompanied by the implementation of alternative models in several specific countries. For instance, medical units of militaries e.g., the Indian Armed Forces Medical Services, store 6 months' worth of short shelf-life items and 8 months' worth of long-shelf-life items, to create capacity for fast disaster relief (14). Finland, likewise, understood the importance of stockpiling since World War II and kept at it consistently while neighboring Nordic countries like Sweden, Denmark and Norway eventually abandoned their stockpiles (15). Finnish pharmaceutical companies, healthcare units and importers were thus mandated to stockpile medications for up to 3–10 months while being compensated by the government for the cost of preserving such reserves. These models are not without their challenges. Significant variations in supply chain performance arise in individual countries. Some of the existing challenges include lack of a single national procurement unit, disorganized supply chains and most importantly bureaucratic inefficiencies which cause delays across the entire continuum and hence compromise appropriate preparedness for pandemics (13, 16). Information on the current/ongoing efforts is detailed elsewhere (**Supplementary Material**).

Low Initial Supplies

Regardless of the supply-chain model, the current global stockpile has been insufficient to support the health system of any country during the pandemic. As of 4 March 2020, the Department of Health and Human Services declared that the United States (US) had ∼12 million N95 masks and 30 million surgical masks, making up a mere 1% of the actual required numbers during the pandemic (2). The shortage was exacerbated by the extraction in the US of the 100 million masks held in the national strategic stockpile during the 2009 H1N1 pandemic, as none of these extracted masks were subsequently restocked (17). Similarly, Australia faced a great shortage of masks from the outset of the pandemic. In January 2020, the National Medical Stockpile of Australia was reported to have a stockpile of only 12 million masks (18). However, during the 2009 H1N1 pandemic, the same agency held 40 million masks in reserve (19), implying a lack of restocking since the previous pandemic, more than a decade ago.

Low Supply From Suppliers

As the virus became pandemic, countries then took steps to protect local supplies (20). China, which normally produces half the global supply of masks at approximately 10 million masks daily, ramped up production to 115 million daily during the early phases of COVID-19 (20). However, the Chinese government simultaneously terminated all mask exports leading to a gradual depletion of global stockpiles. Germany banned the export of the majority of its PPEs (21). In other areas, where local production is not significant, vulnerabilities in the procurement of essential equipment arose. For example, Australia, which imports 90% of its medications, is vulnerable to shortages should supply be impeded (13, 22).

Sudden Rise in Demand

The exhaustion of PPEs, including masks, and ventilators early in the pandemic led to a rapid plummet in available supply just as an international surge in demand arose in late February and March. The figures are tragic: In 2019, a mere 77,000 ventilators were required globally (11). However, as of 11 March 2020, the US alone required 60,000–160,000 ventilators (4). By mid-April, reports of shortages in critical chemical compounds required to produce essential medicines were rising. The production of other medications might be impeded too, especially if certain required pharmaceutical ingredients can only be sourced from countries that happen to be severely affected by COVID-19. The most important example would be

China which exported many raw materials but was temporarily under an economic shutdown. Fortunately, the Food and Drug Administration (FDA) in the US reported shortages of just one drug (22). It is being discussed that the lack of national and public health led cohesive pandemic response and alacrity may have contributed to the rapid increase in cases and high fatality rates.

Breakdown of Trust Among Supply Chain Stakeholders

The COVID-19 has exposed the fragility of our existing supply chain frameworks. Increasing reports on lack of trust and pressures between various stakeholders have been reported (23). This can be attributed to the presence of middlemen or intermediaries (for contracts and procurements between supplier and buyer), who presumably use opportunistic and unfair business practices underpinning lack of transparency in reporting of stock supply numbers and the ambiguity in movements of transactions. This creates an environment which is fertile for speculation, leading to a breakdown of trust and hence the inter-institutional relationships. In a pandemic setting, this could have disastrous consequences. This is especially poignant as buyers don't believe the data coming from suppliers/middlemen, especially during crises (24, 25).

PROPOSAL FOR NEW STRATEGIES OF THE SUPPLY CHAIN TO MEET PANDEMICS SHORTFALL

During pandemics, global supply chain systems security and capacity are challenged (26, 27). To this end, technologies such as blockchain, big-data analytics and artificial intelligence could act as enablers toward building robust supply chain models for future (28, 29). In the current proposal, we propose a supply-chain integration framework, that is built around strong governance, minimal bureaucracy and uses technology (e.g., blockchain) as a connector for direct linkages between supply chain stakeholders (buyer and suppliers), that could potentially address the gaps, reduce inefficiencies and build resilient systems. The new proposed supply chain model will optimize inventory and product recall, streamline processes, smoothen procurement and liaison with the suppliers especially the international manufacturers and will provide leadership and accountability in public health crises such as pandemics. It will leverage blockchain technology as connectors between the stakeholders to automate tasks connecting the suppliers directly to the organizations, hence cutting the intermediary while automating audit and reporting on process-related tasks. Hospital-supplier integration has been proven to improve hospital supply chain performance (30). Furthermore, trust enhances the strategic relationship

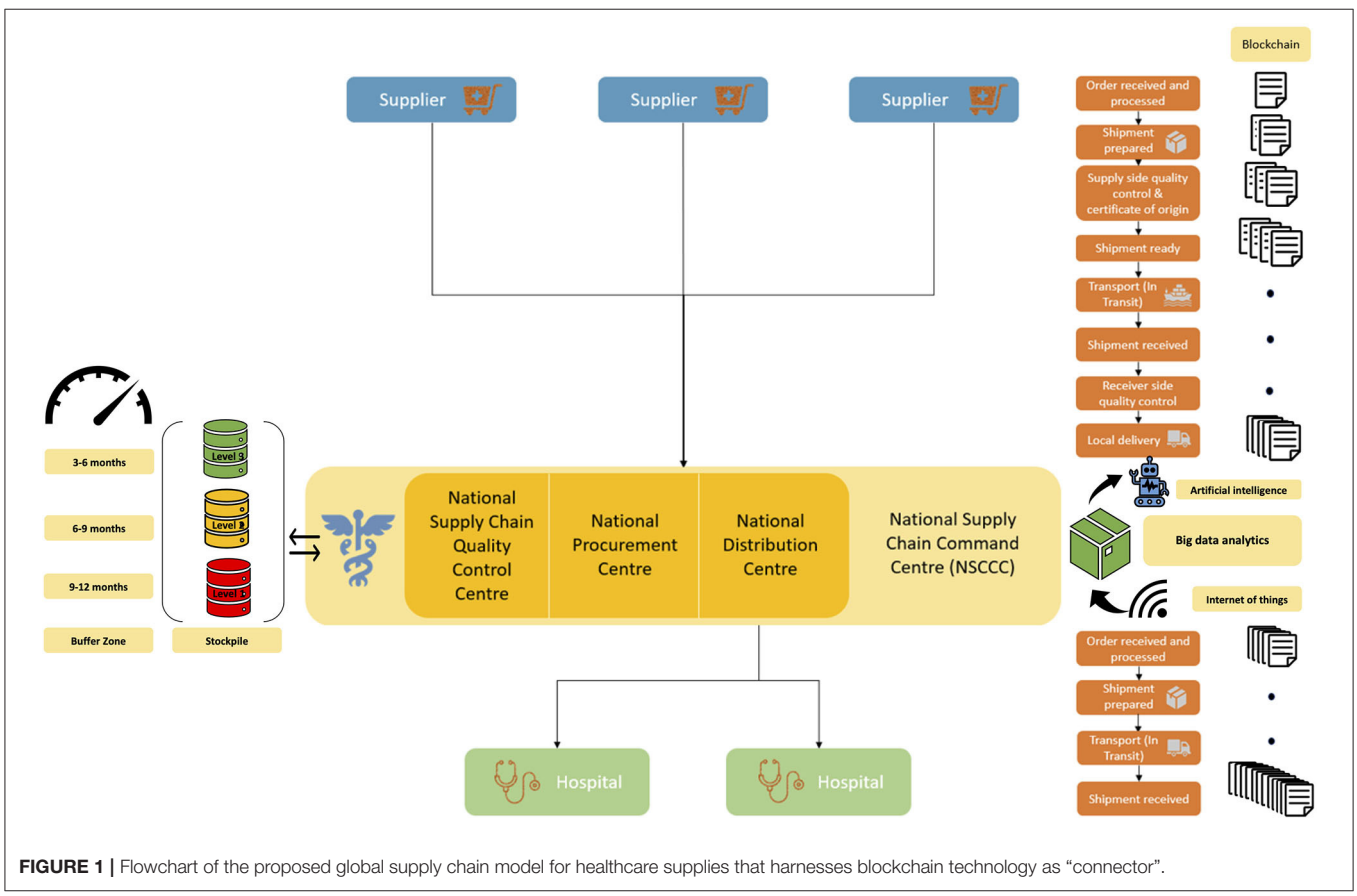

FIGURE 1 | Flowchart of the proposed global supply chain model for healthcare supplies that harnesses blockchain technology as "connector".

and integration which is mutually beneficial to both hospital and supplier (31). This proposal consists of various elements including governance and organizational structure for supply chain (**Figure 1**).

The proposed model consists of the following elements:

(1) **A National Supply Chain Command Centre (NSCCC)** is formed with representations of chief medical officers, independent domain experts (including supply chain, infectious disease, public health, pharmaceuticals etc.), operational experts with appropriate representations from individual states and the federal government. The NSCCC will oversee the procurement and distribution of all health and medical supplies from the country. It will also act as the one-stop command center for regular operational demand and supplies as well as for pandemics or public health emergencies.

(2) Under the NSCCC, three arms will be constituted: **National Procurement Centre, National Supply Chain Quality Control Centre and National Distribution Centre.**

(3) **The National Procurement Centre** will be responsible for opportunity assessment, engagement, sourcing strategy, tendering, invitation to supply, evaluation and negotiation of contracts, implementation of contracts, and purchase of contracts. It will also be responsible for creating purpose-driven inventory checklists to identify the necessary medical supplies for pandemics. The National Procurement Centre will liaise with the National Supply Quality Control Centre to ascertain needs amidst ongoing and evolving crises such as pandemics.

(4) **The National Supply Chain Quality Control Centre** will ensure due diligence in the quality, staged wise stockpiling and appropriate time-buffer for pandemic requirements, and for non-pandemic stocks with pandemic inventory be given high priority and longer buffer/stock period. This stockpile will have three levels of procurement and buffering period: **Level 1** (***Red***) will cater to pandemic needs such as PPEs, surgical and N95 masks, oxygen cylinders, mechanical ventilators and telemedicine capacity including software that can be deployed. There will be a buffer zone of 9–12 months' worth of safety stock. **Level 2 (*Yellow*)** will cater to the supplies of pharmaceuticals and devices inventory that don't have a short expiry period. There will be a buffer zone of 6–9 months' worth of safety stock. **Level 3 (*Green*)** will cater to drugs, medical supplies and devices for non-immediate use. There will be a buffer zone of 3–6 months' worth of safety stock.

(5) **The National Distribution Centre** will be the one-stop center that meets the demands of individual hospitals by directly supplying them. This would ensure supply chain consolidation, the economics of scale, efficiency of processes, and optimized distribution. Each hospital will have its own local supply chain operations unit to ensure the local demands of the individual wards and other facilities are met.

(6) **Blockchain as "connector":** In today's world, global supply chains are dynamic where factors such as the life cycle of drugs and medical devices, varying periods of demand surge and decline make the current supply chain complicated. This is further exacerbated in crises such as pandemics (27). Blockchain addresses the global healthcare supply chain from an "ecosystems" approach which provides an integrated view of the elements (29). Blockchain synchronizes data transactions across the network, where each stakeholder can verify the work and calculations. It builds access to reliable, real-time, digital ledger of information on all these transactions across the relevant timepoints ("time and process audit stamp") in the continuum of the supply chain and process (32). This helps build trust between stakeholders who can access relevant operational details on the supply chain while also allowing stakeholders to negotiate better deals on better terms, cutting down delays between the signing of the contract and product delivery. From an operational and feasibility perspective, it is worthwhile to note blockchain can leverage existing digital infrastructure such as enterprise resource planning (ERP) software, allowing for easy deployment through integration as a single layer onto the existing platform (32, 33). Blockchains can make a huge impact on bringing transparency, improving efficiency and delivery during extended periods of crisis (27). It also cuts down intermediaries and serves as a platform for stakeholders to share data in real-time.

(7) **Predictive big-data analytics in supply chain demand forecasting:** The proposed model, built on blockchain technologies, can indeed make use of complementary predictive big-data analytical applications to address future demands through customer behavior analysis, trend analysis, and demand prediction (34). Data collected through the Internet of things (IoT) can also feed real-time data from various sources for big-data analytics (35). The predictive analytics uses various algorithms (e.g., time-series forecasting, support vector machines, K-nearest-neighbors, neural networks) in supply chain demand forecasting to allow the stakeholders to prepare supplies in advance (34). This could also include artificial intelligence platforms toward data-driven proactive demand forecasting which could be useful during infectious disease outbreaks (35). Furthermore, these predictive algorithms can be trained or optimized on the demand and supply data from the current COVID-19 pandemic or previous infection outbreaks such as H5N1 Avian influenza and Ebola outbreaks. Epidemiological studies and modeling should be used to predict the locations of future demand spikes too (36).

The proposed model implements a staged-wise supply chain strategy. Concurrently, manufacturing companies should map out their entire supply chain allowing for more swift decision making. Identifying companies that can produce masks during crises or providing incentives for companies to set up masks production facilities in peacetime that can then be ramped up. Unfortunately, many manufacturers are unwilling to do so due to the perceived large amount of manpower and time (26). Manufacturers should also branch out to more suppliers and consider paying more for backup suppliers in the event of supply disruptions (5).

To mitigate the risk of product expiry, governments may step in to cover the cost of replacing expired products held within stores (37). Ensuring all parts of the "ecosystem" are involved and engaged is important to enabling open innovation across organizational and regional boundaries (38, 39). There needs to be a connection with how much utilization is so that supply can stay ahead of the curve. This can be done through logistics tracking enabled via artificial intelligence (40). Individual users can design, sew and wear their masks, reducing demand on hospital-grade supplies. This is applicable not only for masks but also other critical essential equipment such as ventilators, other PPEs. Some emergency medicine physicians are adapting ventilators to support multiple patients, for example (41–43).

Regional Stockpiling

Regional stockpiling is another dimension that merits further consideration (44). The Association of Southeast Asian Nations (ASEAN) countries with Japan has made a similar effort previously for avian influenza (45). In the context of COVID-19, the South Asian Association for Regional Cooperation (SAARC) leaders have set-up a COVID-19 emergency fund (46). Such efforts need to be built around a normative framework and institutional arrangements such as the international health framework, created by the WHO's 2005 International Health Regulations (IHR) (47). The 2005 WHO IHR framework pivots around the notion of due diligence (48), the principle of no-harm, and principles of general international law and international human rights law (47). Notwithstanding the limited efficacy and implementation of these initiatives in the past due to regional politics and vested interests, regional approaches to enhance global health security should be intensified (49). We recommend that regional stockpiling infrastructure and framework should be considered and actively pursued for Asia, Middle East, North and South America, Africa and Asia-Pacific regions and that the public-private partnership models be explored.

Eventually, with the proposed streamlined supply chain model, not only will the systems be robust enough to meet demand and supply during pandemics, but the ongoing demands of medical supplies will be appropriately addressed and actioned. This proposal will create a centralized organ that will have proper governance and quality control structures to address future pandemics. Additionally, a hidden army of individuals can contribute user-based designs for masks, gloves, and gowns. Our model would also enable philanthropic groups to identify areas of greatest need and mobilize support for those areas. The public sector must also adapt in these times, to support this initiative. Normal regulatory processes must be accelerated tremendously to get PPEs from this supply chain to those who need it most urgently. If a regulator approves a ventilator for sale in Japan, that approval should have standing in Germany and the US, provided that the approval process and supporting data are provided openly and transparently. Regulators must align their respective procedures and approaches in that regard. Product liability rules that protect consumers should be temporarily relaxed (50), as consumers will be more protected if and when front-line medical staff and other first responders have adequate access to PPEs.

POLICY IMPLICATIONS FOR REGULATION AND GOVERNANCE: THE IMPORTANCE TO EMBED RAPID RESPONSES WITHIN SUSTAINABLE REGULATORY SET-UPS

The aforementioned need for accelerated regulatory approval pathways merits considerations of significant accompanying legal implications. Society should be willing to accept somewhat higher risks—if accompanied by transparency and robust informed consents—during this crisis period in return for faster availability of crisis relevant products. But to find more sustainable solutions that protect consumers, patients and healthcare workers, incentivise value-based innovation and enhance global multi-sector collaboration, it is also important to appropriately consider established standards and legal frameworks to the greatest possible extent. While radical emergency responses to ramp up crisis-critical supplies and encourage open innovation can be very nuanced and do not necessarily have to break with rules and traditions of the innovation system (51), such approaches may challenge the legal system as we know it.

Our proposed initiatives must be embedded in the wider legal frameworks and initiatives. These include recent efforts to create voluntary patent pledges and intellectual property (IP) pools, as well as more invasive approaches to increase access to essential technologies through compulsory licensing (52); and competition law (comfort letters by competition authorities, Canada sunset clause, etc.). Yet, many forms of data and know-how protection would often be excluded from these initiatives. We, therefore, call for an international framework for open-source platforms and through international institutions, such as the WHO that also facilitates the Findable, Accessible, Interoperable and Reusable (FAIR) data sharing (53). In the long-term, it will therefore also be important to consider "stick and carrots." This could include harsh responses by antitrust law to "excessive pricing" and "collusion," but also fair and reasonable compensation for IPR and data holders, as well as clarity and transparency about both demands and rewards.

Similar considerations must be made with regards to the privacy and data protection implications of the employed technologies, such as blockchain and product tracking or other surveillance systems that could help to stem the spread of coronavirus (54) and facilitate open innovation. This requires finding a balanced middle ground which respects essential privacy principles and democratic rights but also makes sure that overly restrictive data protection rules do not prevent necessary, effective and proportionate measures in the fight against the coronavirus pandemic (55). Lastly, for such an organizational and governance framework to succeed, an autonomous structure is envisioned that's not intimidated by the nation or institutional bureaucracies.

CONCLUSION AND RECOMMENDATIONS

Current pandemic has exposed the supply chain and responsiveness of the institutions. The COVID-19 has also forced development and adoption of new triage and patient

management protocols or pathways to minimize risks to patients, healthcare workers and health systems (7, 56–58), and to maintain patient continuity, using telemedicine, especially to those at high risk of infections or with underlying chronic illnesses (8, 9, 28). The outcry for PPEs especially among healthcare workers, at the forefront of the crisis, warrants overhaul of systems. Political leadership is also being scrutinized and its inefficiencies are getting revealed (59). A robust global supply chain combined with public health strategies and/or interventions such as masks, healthcare worker protection, quarantine, contact tracing, massive testing and travel restrictions could limit rapid COVID-19 spread and build the capacity of our institutions to respond to future pandemics. The army of user contributors should also be crowdsourced and mobilized for this effort.

We suggest that the current "lean" based approaches of the healthcare supply chain model are not appropriate for healthcare and may compromise the economic, global health and national security in crisis such as COVID-19. A scaled open innovation approach, that can provide the buffer to the system should an acute and prolonged need emerge, should be part of future global supply chain systems. This would ensure continued provision of essential healthcare supplies and resilience of the healthcare systems. Technology such as blockchain can act as drivers to further improve the efficiency of supply chains.

Additional efforts and resources will be required to achieve a truly global response that comprises all regions of the world and in particular those which are likely to face the most severe consequences. This requires careful consideration of regional disparities in terms of economic capacities, technical infrastructures and cultures. Most importantly, to be better prepared for the next pandemic it will be important to learn lessons from the current COVID-19 crisis to improve global fast-track emergency procedures and global stockpiles with several suppliers on a more sustainable level. Building on the proposed supply chain model, aspects of integration and implementation of national public health policies would also need to be considered. Ideally, the processes that lead to these solutions should be characterized by more effective interdisciplinary collaboration, evidence-informed decision-making, proportionality, flexibility, precautionary approaches combined with established practices, improved regulatory frameworks and ethical decision-making. Good governance, openness and collaboration will be key to effectively fast-track responses–even in the next pandemic. It is therefore important that time-limited radical responses, required right now, will be re-evaluated when the situation improves, to achieve a more dynamic and adaptable but still sustainable model in times of crisis.

The COVID-19 is undoubtedly a public health crisis of a scale not witnessed in a century (60). Fears of impending economic crises reminiscent of the "great depression" abound. Should the economic doomsday predictions come true, the already challenged global health status could take a downward spiral with long-term implications for health and well-being of people (61). Therefore, a crisis like this warrants an unprecedented global effort. Lukewarm responses of governments and health care institutions in determining what work is essential and what the correct PPE is for each situation has caused the build-up of anxiety, confusion, possible increased viral transmission and misuse of PPE (62). Public awareness campaigns on the need to use masks and gloves have also been confusing. As a result of the confusion, the public and healthcare staffs are generally left to look after themselves and use their own. Therefore, clear public health and occupational safety policies and guidelines should be developed for implementation right from the hospital level to the national level to increase public and healthcare workers' adherence to best practices in adherence to infection control including the practice of wearing PPEs, hand-washing and social-distancing (63). Coupled with a lack of regulation, this has seen a surge in the number of "intermediaries" buying and selling PPEs. Moreover, existing "lean" based approaches of healthcare supply chain models have resulted in a shortage of PPEs, possibly compromising economic, health and national security.

In the advent of a lock-down and strained global supply chains, the lack of policies or frameworks to ensure the limited PPEs reach those who need it most (healthcare workers) has caused an outcry, warranting an overhaul of existing systems. Perhaps by enforcing such regulation, that guarantees the provision of critical supplies to protect healthcare workers while they continue to treat patients, the deaths of healthcare workers could be avoided (64–66). We thus call for an international body such as the United Nations to create and implement the proposed framework through which private- and public-sector institutions analyze, restructure and implement new systems to ensure that health-system resilience is no longer compromised by the failure of global supply chains. Such a body would be complementary to the WHO and would amplify its impact. The COVID-19 Technology Access Pool (C-TAP) launched by the WHO, aimed at equitable distribution of medical supplies, can also be a potential solution (67). The C-TAP initiative would allow worldwide sharing of patents covering pharmaceuticals, vaccines, and/or methods of treatment related to the COVID-19. Call for waiver of IP rights to World Trade Organization, by countries like South Africa and India, to enable widening of, and ease of, access to, COVID-19 drugs, diagnostics and vaccines, especially by low-income countries is a promising development toward ensuring equitable access (68). European Commission has also released antitrust guidance to allow limited cooperation among companies, concerning critical hospital medicine shortages during the COVID-19 outbreak (69).

A robust global supply chain combined with public health strategies and/or interventions such as contact tracing would build the capacity of our institutions to respond to future pandemics. In this way, we will not only be able to address the urgent needs across the world—not the least in developing countries—but also be better prepared for the next pandemic.

LIMITATIONS

We acknowledge that the real-world implementation of the model proposed in this article and the global coordination depends on several factors including good relations between the participating countries which is subject to several geopolitical

and diplomatic considerations. Given the current geopolitical situation, its feasibility for a global roll-out may be challenging. However, we believe the implementation should be pursued in a stage-wise plan with the initial implementation, to begin with, to involve countries more amenable to collaboration. This requires to enable openness and collaboration across levels of analysis, for example, not only across organizations but also on an international level (38). Nevertheless, the modular nature of the proposed supply chain model makes it appropriate for scaling-up, including at a global level. Furthermore, a pilot implementation would also provide data for further improvement in improving the system's workflows.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Materials**, further inquiries can be directed to the corresponding authors.

AUTHOR'S NOTE

The COVID-19 pandemic is causing an unprecedented public health crisis impacting healthcare systems, healthcare workers, and communities. The COVID-19 Pandemic Health System REsilience PROGRAM (REPROGRAM) consortium is formed to champion the safety of healthcare workers, policy development, and advocacy for global pandemic preparedness and action.

AUTHOR CONTRIBUTIONS

SB devised the project, the main conceptual ideas, including the proposal for the blockchain-based supply chain model, the proof outline, and coordinated the writing and editing of the manuscript. SB and JT wrote the first draft of the manuscript. SB encouraged JT to investigate and supervised the findings of this work. All authors discussed the results and recommendations and contributed to the final manuscript. This paper could only consider developments until April 30, 2020, at the time of manuscript writing and submission. However, some updates were considered and added during the revision of the manuscript in October 2020. It can, however, be expected that some of these initiatives will meet reluctance or outright opposition from major industry stakeholders. The opinions expressed in this article are those of the authors and do not necessarily represent the decisions, official policy or opinions of the affiliated institutions.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2020.562882/full#supplementary-material

REFERENCES

1. Institute for Health Metrics and Evaluation. *COVID-19 Projections*. (2020). Available online at: https://covid19.healthdata.org/projections (accessed April 5, 2020).
2. CNBC. *HHS Clarifies US Has About 1% of Face Masks Needed for "Full-Blown" Coronavirus Pandemic*. (2020). Available online at: https://www.cnbc.com/2020/03/04/hhs-clarifies-us-has-about-1percent-of-face-masks-needed-for-full-blown-pandemic.html (accessed April 21, 2020).
3. Ranney ML, Griffeth V, Jha AK. Critical supply shortages—the need for ventilators and personal protective equipment during the covid-19 pandemic. *N Eng J Med*. (2020) 382:e41. doi: 10.1056/NEJMp2006141
4. Center for Health Security, John Hopkins Bloomberg School of Public Health. *Ventilator Stockpiling and Availability in the US*. (2020). Available online at: http://www.centerforhealthsecurity.org/resources/COVID-19/200214-VentilatorAvailability-factsheet.pdf (accessed April 21, 2020).
5. Netland T. *A Better Answer to the Ventilator Shortage as the Pandemic Rages On*. World Economic Forum (2020). Available online at: https://www.weforum.org/agenda/2020/04/covid-19-ventilator-shortage-manufacturing-solution/ (accessed April 21, 2020).
6. World Health Organisation. *Shortage of Personal Protective Equipment Endangering Health Workers Worldwide*. (2020). Available online at: https://www.who.int/news-room/detail/03-03-2020-shortage-of-personal-protective-equipment-endangering-health-workers-worldwide (accessed April 21, 2020).
7. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) Settings: recommendations from the REPROGRAM

consortium. *Front Cardiovasc Med.* (2020) 7:112. doi: 10.3389/fcvm.2020.00112
8. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system REsilience PROGRAM (REPROGRAM) international consortium (Part 2). *Front Public Health.* (2020) 8:410. doi: 10.3389/fpubh.2020.00410
9. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine across the globe-position paper from the COVID-19 pandemic health system resilience PROGRAM (REPROGRAM) international consortium (Part 1). *Front Public Health.* (2020) 8:556720. doi: 10.3389/fpubh.2020.556720
10. Manjoo F. *How the World's Richest Country Ran Out of a 75-Cent Face Mask.* New York Times (2020). Available online at: https://www.nytimes.com/2020/03/25/opinion/coronavirus-face-mask.html (accessed April 5, 2020).
11. American Association for Respiratory Care. *Mass Casualty Ventilation and the STRATEGIC National Stockpile.* (2020). Available online at: https://www.aarc.org/webcasts/mass-casualty-ventilation-and-thestrategic-national-stockpile (accessed April 21, 2020).
12. Adebanjo D, Laosirihongthong T, Samaranayake P. Prioritizing lean supply chain management initiatives in healthcare service operations: a fuzzy AHP approach. *Prod Plann Control.* (2016) 27:953–66. doi: 10.1080/09537287.2016.1164909
13. Coorey P. *Australia Dangerously Dependent on Medical Imports.* Australian Financial Review (2020). Available online at: https://www.afr.com/politics/federal/australia-dangerously-dependent-on-medical-imports-20200217-p541ej (accessed April 21, 2020).
14. Kadyan A. Management of medical stores in Indian Armed Forces. *J Def Stud.* (2010) 4:61–81.
15. New York Times. *Finland, "Prepper Nation of the Nordics," Isn't Worried About Masks.* (2020). Available online at: https://www.nytimes.com/2020/04/05/world/europe/coronavirus-finland-masks.html (accessed April 21, 2020).
16. Biesecker M. *US "Wasted" Months Before Preparing for Coronavirus Pandemic.* The Associated Press (2020). Available online at: https://apnews.com/article/090600c299a8cf07f5b44d92534856bc (accessed April 21, 2020).
17. Queen K. *What Supply Chain Players are Learning From the Pandemic.* SME (2020). Available online at: https://www.sme.org/technologies/articles/2020/march/what-supply-chain-players-are-learning-from-the-pandemic/ (accessed April 21, 2020).
18. Craw V. *National Medical Stockpile Could be Used if Coronavirus Reaches Pandemic Status in Australia.* News.com.au (2020). Available online at: https://www.news.com.au/lifestyle/health/health-problems/national-medical-stockpile-could-be-used-if-coronavirus-reaches-pandemic-status/news-story/5ae4bee5c729082bf735998481c61f8d (accessed April 21, 2020).
19. ABC News Australia. *Flu Fears Spark Rush on Pharmacies.* (2020). Available online at: https://www.abc.net.au/news/2009-05-01/flu-fears-spark-rush-on-pharmacies/1668426 (accessed April 5, 2020).
20. Bradsher K, Alderman L. *The World Needs Masks. China Makes Them, but Has Been Hoarding Them.* New York Times (2020). Available online at: https://www.nytimes.com/2020/03/13/business/masks-china-coronavirus.html (accessed October 9, 2020).
21. Reuters.com. *Germany Bans Export of Medical Protection Gear due to Coronavirus.* (2020). Available online at: https://www.reuters.com/article/health-coronavirus-germany-exports/germany-bans-export-of-medical-protection-gear-due-to-coronavirus-idUSL8N2AX3D9 (accessed April 21, 2020).
22. Scipioni J. *Drug Shortage Experts: What Consumers Need to Know During the Coronavirus Pandemic.* CNBC (2020). Available online at: https://www.cnbc.com/2020/03/25/drug-shortage-experts-what-consumers-should-know-in-covid-19-pandemic.html (accessed October 9, 2020).
23. Degnarain N. *Five Ways Blockchain Can Unblock the Coronavirus Medical Supply Chain.* Forbes (2020). Available online at: https://www.forbes.com/sites/nishandegnarain/2020/03/22/5-ways-blockchain-can-unblock-the-coronavirus-medical-supply-chain/#5414b69b1380 (accessed April 21, 2020).
24. Ibbetson R. *China 'Forces Italy to BUY Medical Supplies it had Donated to Beijing*'. Dailymail.co.uk (2020). Available online at: https://www.dailymail.co.uk/news/article-8193197/China-forces-Italy-BUY-masks-coronavirus-supplies-donated-Beijing.html (accessed April 21, 2020).
25. Winter A. *China Selling Coronavirus Face Masks to Highest Bidders in the West After Stockpiling 2 Billion Before Crisis Escalated.* The Sun (2020). Available online at: https://www.thesun.co.uk/news/11314924/china-coronavirus-masks-stockpiling-two-billion/ (accessed October 9, 2020).
26. Choi TY, Rogers D, Vakil B. *Harvard Business Review. Coronavirus Is a Wake-Up Call for Supply Chain Management.* (2020). Available online at: https://hbr.org/2020/03/coronavirus-is-a-wake-up-call-for-supply-chain-management (accessed April 21, 2020).
27. Shih WC. *Global Supply Chains in a Post-Pandemic World.* Harvard Business Review (2020). Available online at: https://hbr.org/2020/09/global-supply-chains-in-a-post-pandemic-world (accessed October 9, 2020).
28. Bhaskar S, Bradley S, Sakhamuri S, Moguilner S, Chattu VK, Pandya S, et al. Designing futuristic telemedicine using artificial intelligence and robotics in the COVID-19 era. *Front Public Health.* (2020) 8:556789. doi: 10.3389/fpubh.2020.556789
29. Gaur V, Gaiha A. *Building a Transparent Supply Chain.* Harvard Business Review (2020). Available online at: https://hbr.org/2020/05/building-a-transparent-supply-chain (accessed October 9, 2020).
30. Alshahrani S, Rahman S, Chan C. Hospital-supplier integration and hospital performance: evidence from Saudi Arabia. *Int J Logistics Manag.* (2018) 29:22–45. doi: 10.1108/IJLM-12-2016-0287
31. Abdallah Ayman B, Abdullah Mais I, Mahmoud Saleh Firas I. The effect of trust with suppliers hospital supply chain performance: the mediating role of supplier integration. *Benchmarking Int J.* (2017) 24:694–715. doi: 10.1108/BIJ-05-2016-0062
32. Banerjee A. Chapter three-Blockchain technology: supply chain insights from ERP. In: Raj P, Deka GC, editors. *Advances in Computers*, *Vol. 111*. London: Elsevier (2018). p. 69–98. doi: 10.1016/bs.adcom.2018.03.007
33. Banerjee A. *Integrating Blockchain With ERP for a Transparent Supply Chain.* Infosys (2019). Available online at: https://www.infosys.com/Oracle/white-papers/Documents/integrating-blockchainerp.pdf (accessed October 9, 2020).
34. Seyedan M, Mafakheri F. Predictive big data analytics for supply chain demand forecasting: methods, applications, and research opportunities. *J Big Data.* (2020) 7:53. doi: 10.1186/s40537-020-00329-2
35. Reidy S. *How the Internet of Things & Big Data Are Accelerating Supply Chain Management.* Supplychain247.com (2020). Available online at: https://www.supplychain247.com/article/internet_of_things_big_data_are_accelerating_supply_chain/arviem (accessed October 28, 2020).
36. Soyiri IN, Reidpath DD. An overview of health forecasting. *Environ Health Prev Med.* (2013) 18:1–9. doi: 10.1007/s12199-012-0294-6
37. Privett N, Gonsalvez D. The top ten global health supply chain issues: perspectives from the field. *Oper Res Health Care.* (2014) 3:226–30. doi: 10.1016/j.orhc.2014.09.002
38. Bogers M, Zobel A-K, Afuah A, Almirall E, Brunswicker S, Dahlander L, et al. The open innovation research landscape: established perspectives and emerging themes across different levels of analysis. *Ind Innov.* (2017) 24:8–40. doi: 10.1080/13662716.2016.1240068
39. Chesbrough H, Bogers M. Explicating open innovation: clarifying an emerging paradigm for understanding innovation. In: Chesbrough H, Vanhaverbeke W, West J, editors. *New Frontiers in Open Innovation*. Oxford: Oxford University Press (2014). p. 3–28. doi: 10.1093/acprof:oso/9780199682461.003.0001
40. DHL Customer Solutions & Innovation. *Artificial Intelligence in Logistics.* (2018). Available online at: https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-trend-report-artificial-intelligence.pdf (accessed October 9, 2020).
41. Branson RD, Blakeman TC, Robinson BRH, Johannigman JA. Use of a single ventilator to support 4 patients: laboratory evaluation of a limited concept. *Respir Care.* (2012) 57:399. doi: 10.4187/respcare.01236
42. Beitler JR, Kallet R, Kacmarek R, Branson R, Brodie D, Mittel AM, et al. *Ventilator Sharing Protocol: Dual-Patient Ventilation With a Single Mechanical Ventilator for Use during Critical Ventilator Shortages. Added April 15, 2020.* Columbia University Vagelos College of Physicians and Surgeons and New

York-Presbyterian Hospital (2020). Available online at: https://protocols.nyp.org/Documents/Ventilator_Sharing_Protocol.pdf (accessed October 9, 2020).
43. Petersen LG, Friend J, Merritt S. Single ventilator for multiple patients during COVID19 surge: matching and balancing patients. *Crit Care*. (2020) 24:357. doi: 10.1186/s13054-020-03041-y
44. World Health Organization, Regional Office for South-East Asia? *Guidelines for the Management of a Regional Stockpile of Oseltamivir*. WHO Regional Office for South-East Asia (2006). Available online at: https://apps.who.int/iris/handle/10665/205173 (accessed October 9, 2020).
45. Japan International Cooperation System (JICS). *JICS Presented the ASEAN Stockpile Project at the ASEAN Senior Officials Meeting Health Development*. (2013). Available online at: https://www.jics.or.jp/jics_html-e/ie/asean201312.html (accessed April 21, 2020).
46. Trivedi A. *Covid-19: Why a New Normative and Institutional Framework for SAARC Nations is Needed to Fight the Coronavirus*. London School of Economics (LSE) Blogs (2020). Available online at: https://blogs.lse.ac.uk/southasia/2020/04/02/covid-19-why-a-new-normative-and-institutional-framework-for-saarc-nations-is-needed-to-fight-the-coronavirus/ (accessed October 9, 2020).
47. World Health Organisation (WHO) Press. *Strengthening Health Security by Implementing the International Health Regulations*. (2005). Available online at: https://www.who.int/ihr/publications/9789241596664/en/ (accessed April 21, 2020).
48. Coco A, Dias TS. *Part I: Due Diligence and COVID-19: States' Duties to Prevent and Halt the Coronavirus Outbreak*. Ejil Talk (2020). Available online at: https://www.ejiltalk.org/part-i-due-diligence-and-covid-19-states-duties-to-prevent-and-halt-the-coronavirus-outbreak/ (accessed October 9, 2020).
49. Katz R, Standley CJ. Regional approaches for enhancing global health security. *BMC Public Health*. (2019) 19:473. doi: 10.1186/s12889-019-6789-y
50. Product Law Bulletin. *Product Law considerations arising from COVID-19*. (2020). Available online at: https://www.rpc.co.uk/-/media/rpc/files/perspectives/insurance-and-reinsurance/product-law-update_d3.pdf (accessed October 9, 2020).
51. Nilsson N, Minssen T. Unlocking the full potential of open innovation in the life sciences through a classification system. *Drug Discov Today*. (2018) 23:771–5. doi: 10.1016/j.drudis.2018.01.002
52. The Pharma Letter. *Canada Moves Compulsory Licensing*. (1992). Available online at: https://www.thepharmaletter.com/article/canada-moves-on-compulsory-licensing (accessed April 21, 2020).
53. Wilkinson MD, Dumontier M, Aalbersberg IJ, Appleton G, Axton M, Baak A, et al. The FAIR guiding principles for scientific data management and stewardship. *Sci Data*. (2016) 3:160018. doi: 10.1038/sdata.2016.18
54. Servick K. *Cellphone Tracking Could Help Stem the Spread of Coronavirus. Is privacy the price?* Science (2020). Available online at: https://www.sciencemag.org/news/2020/03/cellphone-tracking-could-help-stem-spread-coronavirus-privacy-price# (accessed October 9, 2020).
55. European Data Protection Board (EDPB). *Statement by the EDPB Chair the Processing of Personal Data in the Context of the COVID-19 Outbreak*. (2020). Available online at: https://edpb.europa.eu/news/news/2020/statement-edpb-chair-processing-personal-data-context-covid-19-outbreak_en (accessed October 9, 2020).
56. Bhaskar S, Bradley S, Israeli-Korn S, Menon B, Chattu VK, Thomas P, et al. Chronic neurology in COVID-19 era: clinical considerations and recommendations from the REPROGRAM consortium. *Front Neurol.* (2020) 11:664. doi: 10.3389/fneur.2020.00664
57. Bhaskar S, Sharma D, Walker AH, McDonald M, Huasen B, Haridas A, et al. Acute neurological care in the COVID-19 era: the pandemic health system REsilience PROGRAM (REPROGRAM) consortium pathway. *Front Neurol.* (2020) 11:579. doi: 10.3389/fneur.2020.00579
58. Bhaskar S, Sinha A, Banach M, Mittoo S, Weissert R, Kass JS, et al. Cytokine storm in COVID-19—immunopathological mechanisms, clinical considerations, and therapeutic approaches: the REPROGRAM consortium position paper. *Front Immunol.* (2020) 11:1648. doi: 10.3389/fimmu.2020.01648
59. Dying in a leadership vacuum. *N Eng J Med*. (2020) 383:1479–80. doi: 10.1056/NEJMe2029812
60. Cruickshank M, Shaban RZ. COVID-19: lessons to be learnt from a once-in-a-century global pandemic. *J Clin Nursing*. (2020) n/a(n/a). doi: 10.1111/jocn.15365
61. McKee M, Stuckler D. If the world fails to protect the economy, COVID-19 will damage health not just now but also in the future. *Nat Med*. (2020) 26:640–2. doi: 10.1038/s41591-020-0863-y
62. Smith PM, Oudyk J, Potter G, Mustard C. The association between the perceived adequacy of workplace infection control procedures and personal protective equipment with mental health symptoms: a cross-sectional survey of Canadian health-care workers during the COVID-19 pandemic: l'association entre le caractère adéquat perçu des procédures de contrôle des infections au travail et de l'équipement de protection personnel pour les symptômes de santé mentale. Un sondage transversal des travailleurs de la santé canadiens durant la pandémie COVID-19. *Can J Psychiatry*. (2020) 0706743720961729. doi: 10.1177/0706743720961729
63. Karamouzian M, Johnson C, Kerr T. Public health messaging and harm reduction in the time of COVID-19. *Lancet Psychiatry*. (2020) 7:390–1. doi: 10.1016/S2215-0366(20)30144-9
64. Amnesty International. *Global: Amnesty Analysis Reveals over 7,000 Health Workers Have Died From COVID-19*. (2020). Available online at: https://www.amnesty.org/en/latest/news/2020/09/amnesty-analysis-7000-health-workers-have-died-from-covid19/ (accessed October 9, 2020).
65. Agius RM, Robertson JFR, Kendrick D, Sewell HF, Stewart M, McKee M. Covid-19 in the workplace. *BMJ*. (2020) 370:m3577. doi: 10.1136/bmj.m3577
66. Agius RM, Robertson JFR, Stewart M, Kendrick D, Sewell HF, McKee M. *Covid-19: Rigorous Investigation of Healthcare Workers' Deaths is Indispensable*. BMJ Opinion (2020). Available online at: https://blogs.bmj.com/bmj/2020/05/12/covid-19-rigorous-investigation-of-healthcare-workers-deaths-is-indispensable/ (accessed October 9, 2020).
67. World Health Organisation (WHO). *COVID-19 Technology Access Pool*. (2020). Available online at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/global-research-on-novel-coronavirus-2019-ncov/covid-19-technology-access-pool (accessed October 9, 2020).
68. Silverman E. *South Africa and India Urge WTO to Waive IP Rights, Widen Access to Covid-19 Drugs and Vaccines*. Statnews (2020). Available online at: https://www.statnews.com/pharmalot/2020/10/03/wto-covid19-coronavirus-patents-india-southafrica/ (accessed October 9, 2020).
69. European Commission Press Release. *Antitrust: Commission Provides Guidance Allowing Limited Cooperation Among Businesses, Especially for Critical Hospital Medicines During the Coronavirus Outbreak*. (2020). Available online at: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_618 (accessed October 13, 2020).

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Addressing the Covid-19 Burden on Medical Education and Training: The Role of Telemedicine and Tele-Education During and Beyond the Pandemic

Divyansh Sharma[1,2,3] *and Sonu Bhaskar*[1,2,3,4,5]*

[1] *Pandemic Health System REsilience PROGRAM (REPROGRAM) Global, Sydney, NSW, Australia,* [2] *Neurovascular Imaging Laboratory, Clinical Sciences Stream, Ingham Institute for Applied Medical Research, Sydney, NSW, Australia,* [3] *South Western Sydney Clinical School, University of New South Wales (UNSW), Sydney, NSW, Australia,* [4] *Department of Neurology and Neurophysiology, Liverpool Hospital and South West Sydney Local Health District (SWSLHD), Sydney, NSW, Australia,* [5] *NSW Brain Clot Bank, NSW Health Statewide Biobank and NSW Health Pathology, Sydney, NSW, Australia*

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Andreea Molnar, Swinburne University of Technology, Australia

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***Correspondence:**
Sonu Bhaskar
Sonu.Bhaskar@health.nsw.gov.au

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Medical students are the future of sustainable health systems that are severely under pressure during COVID-19. The disruption in medical education and training has adversely impacted traditional medical education and medical students and is likely to have long-term implications beyond COVID-19. In this article, we present a comprehensive analysis of the existing structural and systemic challenges applicable to medical students and teaching/training programs and the impact of COVID-19 on medical students and education. Use of technologies such as telemedicine or remote education platforms can minimize increased mental health risks to this population. An overview of challenges during and beyond the COVID-19 pandemic are also discussed, and targeted recommendations to address acute and systemic issues in medical education and training are presented. During the transition from conventional in-person or classroom teaching to tele-delivery of educational programs, medical students have to navigate various social, economic and cultural factors which interfere with their personal and academic lives. This is especially relevant for those from vulnerable, underprivileged or minority backgrounds. Students from vulnerable backgrounds are influenced by environmental factors such as unemployment of themselves and family members, lack of or inequity in provision and access to educational technologies and remote delivery-platforms, and increased levels of mental health stressors due to prolonged isolation and self-quarantine measures. Technologies for remote education and training delivery as well as sustenance and increased delivery of general well-being and mental health services to medical students, especially to those at high-risk, are pivotal to our response to COVID-19 and beyond.

Keywords: medical education, training, remote delivery, tele-education, telemedicine, technologies, digital humanities, Coronavirus Disease 2019 (COVID-19)

INTRODUCTION

The COVID-19 pandemic is a public health crisis with enormous and diverse social, economic and health consequences (1). Vulnerable and minority groups are being disproportionately impacted, often due to underlying social inequities, health disparities, and comorbidities (2, 3). Medical students are also vulnerable, particularly those from underprivileged or minority backgrounds. However, the plights of medical students in COVID-19 has drawn limited attention. Our previous reports highlighted that frontline medical professionals are vulnerable to mental illness or psychological distress (2, 4, 5). However, medical students are not considered part of the healthcare workforce, lacking access to COVID-19 mental health support available to healthcare workers. We postulate that medical students are especially vulnerable during the pandemic and hence require additional and tailored support, distinct from the general population or medical professionals. Whilst in specific instances or institutions, final year medical students' induction to the healthcare workforce has been expedited to meet increased demands during COVID-19, it's poignant that those in formative years of their education and clinical training have also been removed from structured in-person clinical environments (6, 7). The aim of this article is to critically evaluate the impact of COVID-19 on medical education, training and medical students; and to make targeted recommendations to maintain continuity and support mental health, well-being and education needs of affected students.

METHODS

Relevant literature was identified via PubMed and Medline review, including original, opinion and perspective articles, topic reviews, official national medical associations/bodies and societal guidelines and media sources. The PubMed/Medline search was performed using the keywords "Medical Students," "COVID-19" and "Medical Education" until July 31, 2020. The PICO template, with the population (medical students), intervention (COVID-19), comparator (standard medical education pre-COVID-19) and outcome (impact on medical students/education and changes adopted due to COVID-19), was used. The literature was examined to critically analyse existing structural and systemic challenges of medical education, with an emphasis on the use of technologies such as telemedicine or remote education, and formulate a synthesis on the impact of COVID-19 on medical education, students and training. Appropriate articles relevant to COVID-19 were included in this synthesis. Medical students who are especially vulnerable, such as those with pre-existing mental illness, disadvantaged backgrounds, overseas medical students and those in under-resourced settings are considered and impact of COVID-19 on these subgroups are presented. We also provide targeted recommendations to address acute and systemic challenges during and beyond COVID-19.

RESULTS

Impact of COVID-19 on Medical Students

Medical students are at increased risk of mental or psychological disorders, with a significantly higher prevalence of depression, depressive symptoms and suicidal ideations relative to the general population (8) (**Table 1**). Disruptions in traditional medical education and training due to COVID-19 have increased risk of poor mental health among medical students worldwide (**Table 2**) (8–16). The mental health burden could be exacerbated in those with pre-existing mental illness (4, 42). Concerns around inadequate skill development due to suspension of hospital placements, ambiguity around future prospects and subsequent financial implications have been reported. Poor health behaviors, sleep deprivation during COVID-19 and pre-existing chronic diseases among medical students could adversely affect physical and mental health (29), with cardiovascular disease, diabetes, obesity and chronic neurological comorbidities associated with increased risk of hospitalization and severe illness due to COVID-19. Targeted support and specific recommendations for these subgroups have been made elsewhere (2, 5).

Impact of COVID-19 on Medical Education

Clinical clerkship is fundamental to medical students learning from more experienced practitioners, and becoming more independent and confident clinically (43). The Association of American Medical Colleges (AAMC) released guidelines recommending withdrawal of medical students from clinical environments after the COVID-19 outbreak (44). This was followed by suspension of clinical placements by several Australian medical schools to reduce risks associated with more personnel in clinical environments (45). This trend is true worldwide and has caused widespread concerns from medical students about their learning (46). Lost in-hospital clinical clerkships have caused fears surrounding deficiency in practical skills, training and "imposter syndrome" (17, 20, 46, 47). This extends beyond medical students, with surgical trainees reporting fears around preparedness for surgeries due to the suspension of elective surgeries and face-to-face training (26, 48).

Owing to the climate of uncertainty and limited clinical exposure, concerns surrounding progression through the medical course, training pathways and job prospects have been reported (45, 47, 49), including exploration of alternative career paths (24, 28). This also applies to those at advanced stages in their training, such as trainees and specialists-in-training (26, 28).

Impact of COVID-19 on Medical Students From Vulnerable Groups

Impact on various segments of vulnerable populations within the broad medical students' community is presented below.

Students With Pre-existing Mental Health Issues

The pandemic has caused increased stressors, with social isolation measures particularly associated with, and resulting in, increased depression, anxiety and suicidal ideations, as well as

TABLE 1 | Data illustrating the burden of mental health in medical students.

Parameter	General population (%)			Medical students (Pre-COVID-19) (%)		
	Australia (9)	**UK (10)**	**USA (11)**	**Australia (12)**	**UK**	**USA**
Depression	4.1* (Depressive episode)	3.3***	7.10* (Major depression)	8.1#	9.7###,*** (HADS ≥ 8 (13)	58.2* (14)
Anxiety disorders	14.4* (include OCD and PTSD)	5.9*** (GAD)	19.1*	7.5#	38.4###,*** (HADS≥8) (13)	
Suicidal thoughts/ideations	2.3*	5.4*	4.3*	19.2#	14.9## (15)	9.4* (14)
Eating disorders			BED: 1.2* BN: 0.3* AN: 0.6**			
OCD	1.9*	1.3***	1.2*			
PTSD	6.4*		3.6*			
Substance use disorders	5.1*	Hazardous drinking (AUDIT>8): 19.4* Drug dependence: 3.1*		**Alcohol use** Moderate: 19.0# High: 4.0 # **Daily Use of:** Tobacco: 0.9# Prescription Drugs: 2.6# Illicit Drugs 1–6 times/week: 0.5 #	Hazardous Drinking (AUDIT>8): 50.1###,# (13) Smokers: 3.6###, (13) **Other Substances*** (13) M1: 26.4 M2: 28.4 M3: 23.7	Alcohol abuse/dependence: 32.4 (16)

BED, Binge Eating Disorder; BN, Bulimia Nervosa; AN, Anorexia Nervosa; PTSD, Post-Traumatic Stress Disorder; OCD, Obsessive Compulsive Disorder; GAD, Generalized Anxiety Disorder; HADS, Hospital Anxiety and Depression Scale; M1, 1st Year Medical Students; M2, 2nd Year Medical Students; M3, 3rd Year Medical Students.

**Past Year Prevalence.*

***Lifetime Prevalence.*

****Past Week Prevalence.*

#Current Prevalence.

##During Medical Studies.

###Calculated from study data.

*Note the differing reporting methods and sample sizes. However, it is well-recognized that medical students are at greater risk than the general population. Recent evidence from the COVID-19 pandemic suggests that this is contributing to worsened mental health outcomes in this already vulnerable population; see **Table 2** (25, 29, 41).*

poor health behaviors among medical students during COVID-19 (32, 34), and also medical specialists and trainees (23, 50). This issue is exacerbated by lower uptake of mental health services due to stigma surrounding mental health issues, confidentiality concerns, and the belief that medical students should be self-sufficient in addressing and coping with their mental health issues (51). Social isolation is known to be linked to psychological disorders and/or mental health issues in otherwise healthy individuals, and those with existing mental illness are especially vulnerable, with an increased likelihood of concomitant social factors that can worsen their vulnerabilities (52). These may include conversion disorders, acute stress disorders, mood disorders and frustration (25). Such issues can persist beyond periods of social isolation and are associated with longer-term disorders such as post-traumatic stress disorder symptoms and exacerbation of obsessive-compulsive disorder like symptoms (4), as reported after the severe acute respiratory syndrome outbreak (52). Additionally, medical students currently on psychotherapy or psychiatric interventions may face difficulty in the prescription refill and attending regular therapy sessions (52).

Recent studies show that whilst poor eating behaviors are being seen in the general population, this is more pronounced in those with pre-existing eating disorders (41, 53). Medical students may also be at increased risk of developing eating disorders due to academic and emotional stressors (54). Those with existing eating disorders may be vulnerable to COVID-19 infection and resultant anxiety concerning their health (55). Fears about inability to obtain foods consistent with individual meal plans presumably increases anxiety, and fears of relapse (41, 53). Increased social isolation, gym closures and social media use may also precipitate relapse, and body image concerns, causing withdrawal from engaging with others through video calls, leading to heightened isolation (55). Whilst video-based cognitive behavior therapy (CBT) has shown efficacy, the success of this in pandemic situations is largely unknown (56), with patients in the early transition feeling their quality of care was reduced. Individuals with childhood traumas are also more vulnerable to mental health impacts and warrant special consideration (29).

TABLE 2 | Impact of COVID-19 on medical education, training and mental health of medical students and trainees.

Study	Country/continent or region	Population	Variables/challenges	Impact/assessment
Olum et al. (17)	Uganda/Africa	*n* = 741 1st to 5-year medical students	Knowledge, attitude and practices	Good knowledge, attitude and practices. 80% of students willing to participate in frontline care if required.
Nguyen et al. (18)	Vietnam/Asia	*n* = 5423 Medical students from eight different medical schools	Fear of COVID-19 (via the validated fear of COVID-19 scale)	Better health literacy, older age, later academic years, male gender and better financial status were protective from fear. Those with greater fear scores were more likely to smoke and drink at an unchanged or higher level than before the pandemic.
Flotte et al. (19)	USA/North America	*n* = 57 Final year Medical Students	Students were graduated early and participated in the workforce as limited license physicians	Were able to be deployed in "pods" of 3–4 and provide support to physicians. Received positive feedback.
Compton et al. (20)	Singapore/Asia	*N* = 179 All medical students at a graduate entry medical school in Singapore	Return to the clinical setting	Approximately one-third of students did not wish to return to the clinical setting, with the major concern being negatively influencing patient outcomes.
Chandra et al. (21)	USA/North America	*n* = 67 Senior Medical Students	Concerns around the inability to partake in emergency medicine clinical environments	Online teleconferencing was used to give students the ability to carry out follow-ups with discharged patients. Students reported positive feedback and benefits to their clinical reasoning from discussing with staff members. Additionally, they were pleased with feeling worthwhile in the pandemic.
Collado-Boira et al. (22)	Spain/Europe	*n* = 62 Final year medical (23) and nursing (24) students	Willingness to participate in the health workforce Fears about infection, familial transmission, lack of PPE, confidence in terms of knowledge and skills and coping	85.5% of recipients voluntarily joined, with the major reason being a desire to help in the COVID-19 situation. There were profound fears in all domains, particularly with respect to familial transmission, their practical knowledge and skills, and coping with the death of patients.
Khanna et al. (25)	India/Asia	*n* = 2,355 Ophthalmologists and ophthalmologists-in-training	Impact on training or professional work. Financial Implications. Symptoms of depression using PHQ-9 validated scale	52.8% felt their training or professional would be seriously affected by COVID-19, 37% reported difficulties meeting financial commitments and 32.6% had some degree of depression.
Zingaretti et al. (26)	Italy/Europe	*N* = 115 Plastic surgery residents in Italy	Impacts of COVID-19 on didactic teaching and professional development	Whilst residents reported increased didactic activities compared to pre-COVID, the majority reported them as insufficient. Additionally, most reported their preparedness for operations as either "Not at all" or "Not Much."
Taghrir et al. (27)	Iran/Middle East	*n* = 240 5th to 7th year Iranian Medical Students	Knowledge, preventive behaviors and risk perceptions surrounding COVID-19.	Good knowledge, and high rates of preventative behaviors. Risk perception was moderate but tended to vary between different groups.
Guadix et al. (28)	USA/North America	*n* = 127 1st to 4th Medical Students	Impacts of the COVID-19 pandemic on medical student attendance on neurosurgery training camps	Postponement and cancellation were widespread (76%), and there were profound concerns surrounding conferences and networking opportunities, clinical experience and board examinations. Interestingly, 1st and 2nd-year students wanted virtual mentorship to address this, whereas 3rd and 4th preferred virtual surgical skills workshops.

(Continued)

TABLE 2 | Continued

Study	Country/continent or region	Population	Variables/challenges	Impact/assessment
Li et al. (29)	China/Asia	*N* = 1,442 Health professional students (764 medical, 211 nursing, and 467 medical technology)	Factors associated with psychological distress during the COVID-19 pandemic	26.63% of students had psychological distress that was clinically significant, whilst 11.10% had a probable acute stress reaction. Those with childhood adversity, stressful life event experiences in the past year and internet addiction were at greater risk, whereas good family functioning was protective.
Aker et al. (30)	Turkey/Middle East	*N* = 1,375 Medical Faculty Students	Views surrounding the COVID-19 pandemic	Over half of the students used social media as their source of information, but the majority did not trust this. About half of the students were concerned about receiving education in locations where COVID-19 patients were treated and would not want internships in such locations.
Bhagavathula et al. (31)	Global (308 respondents from Asia)	*n* = 453 Healthcare workers (137 doctors and 134 medical students)	Determination of the knowledge and perceptions related to COVID-19	Most participants obtained their information and knowledge surrounding COVID-19 from social media. Knowledge surrounding incubation period and transmission were poor. Doctors were found to be more well-informed than allied health workers.
Garcia et al. (24)	USA/North America	*N* = 315 (Medical students and foreign medical graduates working at US medical schools)	Determining the impact of the COVID-19 pandemic on medical students considering/already transitioning to neurosurgical careers	Approximately 2/3 of respondents reported postponement of clinical placements and suspended in-person teaching. Greater than 50% of respondents reported reduced academic productivity. One in five first-year medical students reported that they are less likely to pursue neurosurgery as a career option. Student-focused webinars and student-focused sessions at upcoming neurosurgical conferences were favored by students as ways to address these issues.
Liu et al. (32)	China/Asia	*n* = 217	Mental health status of medical students in Wuhan, China	35.5% of students were in a state of depression and 22.1% anxiety. The majority of affected students had mild to moderate symptoms
Khasawneh et al. (33)	Jordan/Middle East	*n* = 1,404 1st to 6th-year medical students	Knowledge, attitude, perceptions, and precautions surrounding COVID-19	Most students obtained their information from social media for information about COVID-19. There was adequate knowledge and appropriate precautionary strategies were carried out.
Meo et al. (34)	Saudi Arabia/Middle East	*n* = 625 1st to 5th-year Medical Students	Psychological well-being, stress and learning behaviors.	Feelings of emotional detachment and disheartenment were prominent. Additionally, students felt their work performance and time spent studying was reduced.
Abbasi et al. (35)	Pakistan/Asia	*n* = 382 Medical and Dentistry Students	Attitudes and perceptions surrounding e-learning	Most students had negative perceptions surrounding e-learning and preferred face-to-face learning. Many students used their mobile devices for e-learning purposes.

(Continued)

TABLE 2 | Continued

Study	Country/continent or region	Population	Variables/challenges	Impact/assessment
Sethi et al. (36)	Pakistan/Asia	$n = 290$ Healthcare professionals	Impacts of the shutdown on daily lives and health	For academics, work-life balance issues were identified as online teaching was an addition to extensive clinical work. Ensuring mental health impacts were reported. For some clinicians in training, academic delays and subsequent financial impacts were a concern. There were concerns about the lack of PPE.
Ikhlaq et al. (37)	Pakistan/Asia	$n = 384$ Medical, dental, nursing and allied health students	Awareness and attitudes	A resounding majority were aware of the etiology, mode of transmission and possible symptoms, but in-depth knowledge was lacking. Medical and nursing students had better knowledge. Most students showed positive attitudes, but a substantial proportion had fears around familial transmission. There were also concerns around the government's ability to address the COVID-19 pandemic.
Lin et al. (38)	China/Asia	$n = 2,086$ Medical students from a single medical school in Fujian, China	Impacts of mass and social media on psychobehavioural responses to the COVID-19 pandemic	Both mass and social media exposure assisted in increasing positive attitudes and reducing emotional consequences and behavioral prevention barriers
Choi et al. (39)	United Kingdom	$n = 440$ Final year medical students from 32 UK medical schools	Impacts on student learning and confidence for their 1st year of training	Significant impacts on student's preparedness due to impacts on OSCEs, written exams and student assistantships. The latter also had confidence implications.
Çalişkan et al. (40)	Turkey/Middle East	$n = 860$ Final year medical students	Knowledge and perceptions toward COVID-19	Moderate knowledge. Those with better knowledge had lesser fear. Most students reported not having been trained until the pandemic hit Turkey. Many students also felt unprepared if required to assist in the emergency department.

Students From Financially Disadvantaged Backgrounds

Telecommunications technology has provided an effective way to address gaps in learning caused by the pandemic. However, for those engaging in online learning, there may be inequities, and subsequent frustration and stress, as even in developed countries, not all students have access to the digital devices or infrastructure required to effectively partake in online learning (57). Moreover, those in remote and rural areas often have poor internet connections (58). Prolongation of the course length can have significant financial consequences and hence impact academic progression (18).

The widespread redundancies, job losses and closure of non-essential services due to COVID-19 have forced several students to resume work to support their families (57). This can negatively affect their ability to engage in online learning activities due to concurrent work responsibilities (18). Medical students from disadvantaged backgrounds reliant on public transport to commute also face greater infection risks.

Students in Developing Countries

Students in developing countries face unique challenges such as limited availability of online teaching resources for medical education (59). The frontline healthcare workers handling COVID-19 associated hospitalizations are limited in their ability to develop teaching resources (36). Given that online teaching modalities have been largely unexplored in many of these countries, these issues have been exacerbated (60). Poor internet access and stability are also reported, causing an unwillingness on students' part to transition to online teaching modalities, and negative perceptions surrounding use of telecommunications technology for learning (35). Perceived poor responses by governments and public leadership have also inflicted psychological stress among students (37).

Students From Minority Groups

Medical students belonging to racial, ethnic and linguistic minority groups face unique challenges due to systemic barriers (61, 62). A 2019 American study showed that white students were more likely to have grading disparities favoring them than minority groups (62). Implicit bias, along with factors such as inappropriate learning environments for minority groups, were reported to drive these disparities. Incorporation of concrete rubrics and marking criteria to limit subjectivity and implicit bias training programs to educate examiners may reduce these (62).

A 2020 study similarly found that underrepresented minorities, Asian and multiracial students, were more likely to be deprived of opportunities based on race than white students (7.3, 4.4, 3.6 vs. 1.5%, respectively) and be subjected to racially offensive comments (18.9, 12.9, 9.6 vs. 2.5%, respectively). Additionally, female students were more likely to be discriminated than males (28.2 vs. 9.4%) (63), and lesbian, gay and bisexual students were more likely to be mistreated than heterosexual students (43.5 vs. 23.6%) (63).

There are concerns that people from racial and ethnic minority backgrounds, already reported to have higher rates of infection and racial discrimination during the pandemic, will present later and at more advanced stages of disease due to fears of structural racism, thereby increasing clustering and community transmission risk (64–66). Systemic issues around underreporting of racial harassment also exist, contributing to increased mental health risks among minority groups, with beliefs existing that complaints pertaining to discrimination will not be taken seriously and/or addressed appropriately (67). To our knowledge, there is limited research into impacts of COVID-19 on the lesbian, gay, bisexual, transgender, queer and intersex (LGBTQI+) community. However, systemic inequalities and inequities are known to cause long-term stress, increasing vulnerability to negative mental health implications. Of particular concern is isolation and separation from trusted family and friends due to quarantine measures (68). Medical students are particularly reluctant to discuss sexual orientation, thereby raising concerns over their ability to seek help (61). Confidential telehealth services have sprung up worldwide and may assist students from minority groups.

International Medical Students

International medical students are particularly impacted, with several institutions shifting to online delivery methods soon after the start/resumption of the academic year (58). Resultantly, there is an increased risk of isolation and subsequent mental health issues, with an Australian study showing that international students have higher baseline depression risk than local students considering loneliness, anxiety and stress scores (69). Additionally, loss of employment, financial insecurity and lack of family support are significant, especially for international students not returning to their home countries (52), as social and family support may be protective against mental health sequelae (29). With university campuses closing down, accommodation may become an issue, exacerbated by job losses from closure of non-essential services (70).

For students having returned to their home countries, concerns surrounding academic progression are likely stressors, amidst new immigration measures including indefinite sealing of borders to non-citizens, temporary-residents or immediate family thereof by several countries (71). Variation in time zones during online learning for overseas courses or seminars may impact sleep cycles, with insufficient sleep associated with various mental disorders including depression (72). Once border restrictions are eased, and foreign students return to their host countries, it may not be feasible for them to return home to loved ones (73, 74). Travel restrictions could prolong course length and incur subsequent financial burden (70).

The inability to access clinical environments is particularly relevant, as engaging with patients and peers of their host country is pivotal to developing cultural competence and understanding socio-cultural norms, expectations and communication methods, along with language skills. Lack of this can be a stressor and contribute to imposter syndromes (75). Telecommunications technology may revive some degree of communication. However, non-verbal body language, pivotal in communication, cannot be adequately simulated (76).

Medical Student Parents

Medical students who are parents may have hindered engagement in interactive learning via telecommunications due to a need to take care of children, which other students might not appreciate, causing feelings of isolation and exclusion, and frustration (77, 78). Additionally, individuals may feel caught between notions of service and personal responsibility to their family, which can have personal mental health implications pertaining to guilt (79).

DISCUSSION AND RECOMMENDATIONS

The COVID-19 pandemic has not only presented acute challenges to medical education and students but also exposed systemic issues that merit consideration. Given the COVID-19 pandemic has had an exacerbated impact on vulnerable populations, including but not limited to students from vulnerable backgrounds; evidently, these students would need targeted interventions, while recognizing the unique challenges in the COVID-19 era and accounting for socioeconomic aspects. Technologies such as telemedicine and tele-education are emerging as important platforms in mitigating the devastating impact of COVID-19 (80–82). Given the acute impact vis-a-vis rising mortality globally (5, 83), and long-term effects of this outbreak that may last beyond the pandemic (2), strategies toward capacity building are necessary.

We provide recommendations to address the negative impacts of the COVID-19 pandemic on medical student mental health and well-being and to build sustainable healthcare and education systems beyond the pandemic.

Technology in Remote Delivery of Medical Education and Training

Restructuring Teaching and Examination Processes

During COVID-19

COVID-19 has led to rapid uptake and development of online teaching to minimize disruption to student learning. Telecommunication technologies are an important component in this, with several institutions having implemented online teaching webinars, simulations and educational clinical skill videos (21, 46). Multimodal teaching approaches catering to various aspects of learning have been implemented (84), along with flipped learning methodologies, which involve students engaging with content prior to class and using later face-to-face time to clarify concepts. This is useful

for teaching anatomy using online 3D modeling applications considering suspension of traditional cadaver-based anatomy demonstration at several institutions (85). Online teaching can be made more engaging and effective for students through interactive tools such as voting polls, chat functions and videos (86). Additionally, intensive anatomy and clinical skills workshops, building on online learning resources, can be run when students return to in-person teaching to address deskilling and imposter syndrome concerns (58). Virtual tools such as virtual reality simulations, homemade simulations and smartphone modalities could benefit surgical trainees (46, 87).

These approaches, reliant on effective use of telecommunications technology facilitate enhanced student pedagogy, and thus address the stressors of deskilling, progression and hindered knowledge. Involvement of students in telehealth to provide clinical exposure and help triage patients during the pandemic has been well-received and facilitates controlled patient exposure with feedback (21). Tele-health-based services to partially replace overseas elective placements, although not equivalent, may allow students to gain an enhanced understanding of another healthcare system (88).

Accelerated progression may help ease burdens on the healthcare system. However, immediate transition into clinical practice could instigate higher rates of work-related stress, and this needs to be monitored (89). Concerns around litigation also exist (90), and mandating indemnity guarantees before students are offered jobs could be a solution. Additionally, students can be recruited into hospitals they are familiar with, to facilitate easier and less stressful transitions (91). Increased repurposing of specialists into different roles to assist with the response to the pandemic, and the increasing reliance on telemedicine, sustained supervision and detailed training are necessary to facilitate a seamless transition (4).

Considering higher levels of baseline stress, anxiety, and mental health implications during the pandemic, and the recency of the changes to learning modalities having been implemented, variations in exam structure could be considered. Open book examinations provide an alternative that could reduce students' stress and anxiety, with some institutions also considering pass/fail grading (92, 93). Additionally, students need education about evidence-based medicine, research methodologies and reliable sources, as several students rely on social media for their information on the pandemic (30, 31, 33). Consequently, medical students can be involved in curating evidence-based recommendations and research, to deepen understanding of bias and confounding, and assist in fighting misinformation in the community (94, 95).

Finally, for those entering clinical environments, targeted training in addressing the unique needs of the COVID-19 pandemic would be necessary, with a recent systematic review suggesting a multimodal training approach, which improves student skills, knowledge and attitudes (96). This would also entail teaching around effective communication using telemedicine, including professionalism and catering for patients with different technological capabilities (97).

Beyond COVID-19

Flipped learning could be of great utility toward encouraging independent learning, an integral part of ongoing medical professional development. Due to limited access to cadavers for medical education, such learning methods may be necessary beyond the pandemic (98) and may provide students greater flexibility. Training or volunteering opportunities to work in infectious disease outbreak settings, particularly via teaching around effective telemedicine consultations, could be embedded into medical school curricula to develop student confidence and resilience should an epidemic occur in future (96, 97).

Considering minority groups, training examiners on the role of implicit biases may facilitate longer-term benefits in education and assessment of medical students, and in establishing equitable and fair training, which will indelibly influence students' mental health positively (62). Finally, the misinformation propagated through social media with regards to this pandemic illustrates the role for doctors to act as educators, which could be a key part of medical school curricula going forward (99). Medical students should also be encouraged to be proactive to gain knowledge about COVID-19, to increase awareness on and contest misinformation (100).

Skill Building

During COVID-19

Incorporating inclusive language in everyday practice is pivotal in preventing marginalization of patients from the LGBTQI+ community, who already experience increased levels of stress and fear (68). Mental health first-aid training can help medical students develop strategies to cope with stressors, and help reduce stigmatizing attitudes toward mental health in the broader community (101, 102), with the Australian Government announcing funding to this end (103).

Webinars by experts from various medical disciplines have set a benchmark toward upskilling students and trainees and maintaining their interest and motivation. Using staggered timings to overcome issues related to time zones has been highly effective and can contribute to a global sense of community (46, 104). One such initiative is a collaborative series of recorded seminars and accompanying associated modules by the American College of Surgeons Division of Education and Association for Surgical Education (105), which specifically assist medical students with core surgical knowledge (105). Numerous institutions have also successfully implemented volunteering initiatives including research, assisting hospital triage, contact tracing, and support hotlines to support medical services during the pandemic but also boost student morale as they develop skills and feel "useful" (21, 106, 107). Telehealth service forms the backbone of such initiatives, allowing students to develop skills safely (108, 109).

Beyond COVID-19

Evaluation of skills development programs and their effectiveness is critical. Should they prove beneficial, their incorporation into regular teaching through telecommunications technology could potentially positively influence medical student and trainee mental health in an accessible and convenient manner. Additionally, considering the unpredictability surrounding

TABLE 3 | Various support services available to doctors and medical students in various countries and regions*.

Country	Name	Website	Hotline number	Mode of delivery
Australia	Drs4Drs support service (114)	http://www.drs4drs.com.au/	1300 374 377 (1300 DR4 DRS)	Phone
United Kingdom	NHS staff support line (115)	https://people.nhs.uk/help/	0300 131 7000	Phone
			Text FRONTLINE to 85258	Text Message (24 h support)
	NHS virtual staff common room (115)		N/A	Zoom Video Conferencing Platform (groups of 10, hosted by practitioners)
	Project5 well-being support service (116)	https://www.project5.org/getsupport	N/A	Online-linked with a "supporter" who is either a Coaching or Mental Health Professional
Canada	Wellness support line (117)	https://www.cma.ca/supportline	Newfoundland and Labrador, Nunavut, Saskatchewan and Yukon: 1-844-675-9222	24/7 hotlines with dedicated Physician and Family Support Program Physicians, who can link callers with relevant services for them
			Ontario: 1-800-851-6606	
			Nova Scotia: 1-855-275-8215	
	Physician health program of British Columbia 24 h helpline (118, 119)		British Columbia and Prince Edward Island: 1-800-663-6729	24/7 hotlines with dedicated intake counselors who can connect callers with physician support
	Quebec physicians' health program (PAMQ) Telephone (117, 119)		Montreal: 1-514-397-0888 Rest of Quebec: 1-800-387-4166	Hotline which allows connection to Physician Advisors
	Alberta Medical Association–Physician and family support program (117, 120)		Alberta: 1-877-SOS-4MDS (767-4637)	24/7 hotline with dedicated Physician and Family Support Program Physicians, who can link callers with relevant services for them
	Doctors Manitoba–Physician and family support program (117)		Manitoba: 1-844-4DOCSMB (436-2762)	Confidential 24/7 hotline
India	Indian Medical Association Psychosocial Counseling Helpline (121)	https://www.ima-india.org/ima/	+91 9999 11 6375 +91 9999 11 6376	Helpline operational 9 am to 9 pm daily
United States of America	Physician Support Line (122)	https://www.physiciansupportline.com/	1 (888) 409-0141	Confidential helpline for physicians run by volunteer psychiatrists. Open 7 days a week: 8:00 AM−1:00 AM ET.

This is not exhaustive, and the information provided was current at the time of writing.

further spread of the virus, and future outbreaks, such programs may inform future methods of addressing pandemics (108).

Telemedicine for Care of General Well-Being and Mental Health of Medical Students

Creation of Mental Health Support Networks

Supporting medical students and trainees should not be limited to times of crisis such as this pandemic, but this pandemic has brought this important issue to the forefront. We discuss various strategies that can foster mental health support networks for students harnessing technology as an enabler (95).

Mentoring groups

During COVID-19. The creation of mentoring groups for students can facilitate sharing of ideas, advice and combating feelings of isolation. This can be particularly beneficial for international students who have not returned home and may feel isolated, as well as minority groups (69). Such groups can be stratified, with senior students providing advice and guidance

to junior students, which may help address stressors related to progression and encourage participation in other areas such as research and peer teaching (110). Discussions with other students can provide a sense of unity and reassure students that they are not alone in feeling "imposter syndrome," with sharing of online resources such as 3D anatomical models also being beneficial (111). Students from various backgrounds, including international, minority and medical student parents can be placed together in groups to facilitate increased understanding of the various challenges others from different backgrounds face, which may assist with developing empathetic competence (111). Such mentoring doesn't need to be faculty-driven but can be led by medical students themselves, who can use existing social media networks and telecommunications to overcome barriers imposed by social distancing policies (104, 111–113).

Beyond COVID-19. Mentoring groups or networks developed during COVID-19 should be continued beyond this pandemic. This would provide students an opportunity to interact with others, and obtain advice and guidance about study, research, and future training prospects (24, 110). Also, the social media-enabled hashtag support networks should be encouraged and propagated, with the "pay it forward" attitude (104, 112).

Tele-Psychiatry and Support Services

During COVID-19. Considering increasing reports of mental health consequences of the pandemic on medical students and trainees, telemedicine can be harnessed to provide constant support to these individuals and resultantly safeguard our future generations of medical professionals from longer-term sequelae. Confidentiality would be crucial to such a system, as many individuals, particularly those from minority groups, are reluctant to share their vulnerabilities (61). Additionally, training psychologists and psychiatrists involved in this service about unique demands of different groups will be critical to providing personalized care (74). Several telepsychiatry and support services have been started worldwide (**Table 3**).

Additionally, CBT has been found to have utility for both depression and generalized anxiety disorder in university students. Although online CBT is not as effective as face-to-face equivalents, COVID-19 precautions and restrictions mean it is a useful way provide students with positive coping skills, and can bypass fears of stigma within medical student populations. Engagement has been problematic with online platforms in the past, and thus constant appraisal and remodeling are critical (123–125).

Beyond COVID-19. Maintenance of such telemedicine services provide medical students and trainees with a convenient and accessible outlet for any mental health concerns they may have and resultantly can assist in early identification or prevention of longer-term impacts of known stressors associated with the medical profession (95). Additionally, normalizing health-seeking behaviors through supportive rhetoric can help overcome barriers related to stigma (51).

Increase Accessibility to Support Services

During COVID-19. Support services are being implemented for vulnerable students. For instance, the NSW state government in Australia has provided funding for crisis accommodation for international students under financial duress due to the COVID-19 pandemic (126). Informing students to whom such support mechanisms are relevant is pivotal, with use of social media, targeted mail-outs, and newsletter segments being possibilities.

Beyond COVID-19. Appraising and optimizing such targeted communication with student subgroups can make them feel more valued and allow early access to any support required. Additionally, incorporating student input into developing programs can make these more effective and targeted to their needs.

Minority groups may be unlikely to make complaints about harassment and bullying for fear of their complaint not being taken seriously or retaliation. To address this, and increase the accessibility of support, public statements of zero tolerance for bullying, harassment and discrimination should be made. Additionally, diversification of staff and complaints committees and incorporation of lived experience members may be useful in highlighting to students that their viewpoints and challenges will be respected and that they will get fair redressal for untoward experiences or incidents (67, 127).

In conclusion, medical students, the future of our healthcare system, are vulnerable during the current pandemic, with subgroups of medical students from specific backgrounds more impacted. Targeted support for these subgroups, and students overall, is warranted. COVID-19 has exposed systemic issues within our healthcare and education systems. Recognizing these issues and developing strategies to combat them is pivotal to our response to an infection outbreak in the future.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

SB contributed to the planning, draft and revision of the manuscript supervision of the student, and encouraged DS to investigate and supervised the findings of this work. SB and DS wrote the first draft of this paper. Both authors contributed to the revision of the manuscript and approved the final draft of the manuscript.

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REFERENCES

1. Varga Z, Flammer AJ, Steiger P, Haberecker M, Andermatt R, Zinkernagel AS, et al. Endothelial cell infection and endotheliitis in COVID-19. *Lancet*. (2020) 395:1417–8. doi: 10.1016/S0140-6736(20)30937-5
2. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) settings: recommendations from the REPROGRAM consortium. *Front Cardiovasc Med*. (2020) 7:112. doi: 10.3389/fcvm.2020.00112
3. Webb Hooper M, Nápoles AM, Pérez-Stable EJ. COVID-19 and racial/ethnic disparities. *JAMA*. (2020) 323:2466–7. doi: 10.1001/jama.2020.8598
4. Bhaskar S, Bradley S, Israeli-Korn S, Menon B, Chattu VK, Thomas P, et al. Chronic neurology in COVID-19 era: clinical considerations and recommendations from the REPROGRAM consortium. *Front Neurol*. (2020) 11:664. doi: 10.3389/fneur.2020.00664
5. Bhaskar S, Sharma D, Walker AH, McDonald M, Huasen B, Haridas A, et al. Acute neurological care in the COVID-19 era: the pandemic health system REsilience PROGRAM (REPROGRAM) consortium pathway. *Front Neurol*. (2020) 11:579. doi: 10.3389/fneur.2020.00579
6. Baker DM, Bhatia S, Brown S, Cambridge W, Kamarajah SK, McLean KA, et al. Medical student involvement in the COVID-19 response. *Lancet*. (2020) 395:1254. doi: 10.1016/S0140-6736(20)30795-9
7. Liang S-W, Chen R-N, Liu L-L, Li X-G, Chen J-B, Tang S-Y, et al. The psychological impact of the COVID-19 epidemic on guangdong college students: the difference between seeking and not seeking psychological help. *Front Psychol*. (2020) 11:2231. doi: 10.3389/fpsyg.2020.02231
8. Rotenstein LS, Ramos MA, Torre M, Segal JB, Peluso MJ, Guille C, et al. Prevalence of depression, depressive symptoms, and suicidal ideation among medical students: a systematic review and meta-analysis. *JAMA*. (2016) 316:2214–36. doi: 10.1001/jama.2016.17324
9. Slade T, Johnston A, Teesson M, Whiteford H, Burgess P, Pirkis J, et al. *The Mental Health of Australians 2: Report on the 2007 National Survey of Mental Health and Wellbeing*. (2009). Available online at: https://www1.health.gov.au/internet/main/publishing.nsf/Content/mental-pubs-m-mhaust2 (accessed July 31, 2020).
10. McManus S, Bebbington P, Jenkins R, Brugha T, editors. *Mental health and wellbeing in England: Adult Psychiatric Morbidity Survey 2014*. Leeds: NHS Digital (2016). Available online at: https://digital.nhs.uk/data-and-information/publications/statistical/adult-psychiatric-morbidity-survey/adult-psychiatric-morbidity-survey-survey-of-mental-health-and-wellbeing-england-2014 (accessed July 31, 2020).
11. National Institute of Mental Health. *Statistics: National Institute of Mental Health*. (2018). Available online at: https://www.nimh.nih.gov/health/statistics/index.shtml (accessed July 31, 2020).
12. Wu F, Ireland M, Hafekost K, Lawrence D. *National Mental Health Survey of Doctors and Medical Students*. Beyond Blue (2013). Available online at: https://www.beyondblue.org.au/about-us/our-work-in-improving-workplace-mental-health/health-services-program/national-mental-health-survey-of-doctors-and-medical-students (accessed July 31, 2020).
13. Bogowicz P, Ferguson J, Gilvarry E, Kamali F, Kaner E, Newbury-Birch D. Alcohol and other substance use among medical and law students at a UK university: a cross-sectional questionnaire survey. *Postgrad Med J*. (2018) 94:131–6. doi: 10.1136/postgradmedj-2017-135136
14. Jackson ER, Shanafelt TD, Hasan O, Satele DV, Dyrbye LN. Burnout and alcohol abuse/dependence among U.S. medical students. *Acad Med*. (2016) 91:1251–6. doi: 10.1097/ACM.0000000000001138
15. Billingsley M. More than 80% of medical students with mental health issues feel under-supported, says student BMJ survey. *BMJ*. (2015) 351:h4521. doi: 10.1136/sbmj.h4521
16. Dyrbye LN, West CP, Satele D, Boone S, Tan L, Sloan J, et al. Burnout among U.S. medical students, residents, and early career physicians relative to the general U.S. population. *Acad Med*. (2014) 89:443–51. doi: 10.1097/ACM.0000000000000134
17. Olum R, Kajjimu J, Kanyike AM, Chekwech G, Wekha G, Nassozi DR, et al. Perspective of medical students on the COVID-19 pandemic: survey of nine medical schools in Uganda. *JMIR Public Health Surveill*. (2020) 6:e19847. doi: 10.2196/19847
18. Nguyen HT, Do BN, Pham KM, Kim GB, Dam HTB, Nguyen TT, et al. Fear of COVID-19 Scale-associations of its scores with health literacy and health-related behaviors among medical students. *Int J Environ Res Public Health*. (2020) 17:4164. doi: 10.3390/ijerph17114164
19. Flotte TR, Larkin AC, Fischer MA, Chimienti SN, DeMarco DM, Fan P-Y, et al. Accelerated graduation and the deployment of new physicians during the COVID-19 pandemic. *Acad Med*. (2020) 95:1492–4. doi: 10.1097/ACM.0000000000003540
20. Compton S, Sarraf-Yazdi S, Rustandy F, Radha Krishna LK. Medical students' preference for returning to the clinical setting during the COVID-19 pandemic. *Med Educ*. (2020) 54:943–50. doi: 10.1111/medu.14268
21. Chandra S, Laoteppitaks C, Mingioni N, Papanagnou D. Zooming-out COVID-19: virtual clinical experiences in an emergency medicine clerkship. *Med Educ*. (2020). doi: 10.1111/medu.14266. [Epub ahead of print].
22. Collado-Boira EJ, Ruiz-Palomino E, Salas-Media P, Folch-Ayora A, Muriach M, Baliño P. "The COVID-19 outbreak" -an empirical phenomenological study on perceptions and psychosocial considerations surrounding the immediate incorporation of final-year Spanish nursing and medical students into the health system. *Nurse Educ Today*. (2020) 92:104504. doi: 10.1016/j.nedt.2020.104504
23. Huckins JF, daSilva AW, Wang W, Hedlund E, Rogers C, Nepal SK, et al. Mental health and behavior of college students during the early phases of the covid-19 pandemic: longitudinal smartphone and ecological momentary assessment study. *J Med Internet Res*. (2020) 22:e20185. doi: 10.31234/osf.io/4enzm
24. Garcia RM, Reynolds RA, Weiss HK, Chambless LB, Lam S, Dahdaleh NS, et al. Letter: preliminary national survey results evaluating the impact of COVID-19 pandemic on medical students pursuing careers in neurosurgery. *Neurosurgery*. (2020) 87:E258–9. doi: 10.1093/neuros/nyaa214
25. Khanna R, Honavar S, Metla A, Bhattacharya A, Maulik P. Psychological impact of COVID-19 on ophthalmologists-in-training and practising ophthalmologists in India. *Indian J Ophthalmol*. (2020) 68:994–8. doi: 10.4103/ijo.IJO_1458_20
26. Zingaretti N, Contessi Negrini F, Tel A, Tresoldi MM, Bresadola V, Parodi PC. The impact of COVID-19 on plastic surgery residency training. *Aesthetic Plast Surg*. (2020) 44:1381–5. doi: 10.1007/s00266-020-01789-w
27. Taghrir MH, Borazjani R, Shiraly R. COVID-19 and Iranian medical students; a survey on their related-knowledge, preventive behaviors and risk perception. *Arch Iran Med*. (2020) 23:249–54. doi: 10.34172/aim.2020.06
28. Guadix SW, Winston GM, Chae JK, Haghdel A, Chen J, Younus I, et al. Medical student concerns relating to neurosurgery education during COVID-19. *World Neurosurg*. (2020) 139:e836–47. doi: 10.1016/j.wneu.2020.05.090
29. Li Y, Wang Y, Jiang J, Valdimarsdóttir UA, Fall K, Fang F, et al. Psychological distress among health professional students during the COVID-19 outbreak. *Psychol Med*. (2020). doi: 10.1017/S0033291720001555. [Epub ahead of print].
30. Aker S, Midik Ö. The views of medical faculty students in turkey concerning the COVID-19 pandemic. *J Community Health*. (2020) 45:684–8. doi: 10.1007/s10900-020-00841-9
31. Bhagavathula AS, Aldhaleei WA, Rahmani J, Mahabadi MA, Bandari DK. Knowledge and perceptions of COVID-19 among health care workers: cross-sectional study. *JMIR Public Health Surveill*. (2020) 6:e19160. doi: 10.2196/19160
32. Liu J, Zhu Q, Fan W, Makamure J, Zheng C, Wang J. Online mental health survey in a medical college in China during the COVID-19 outbreak. *Front Psychiatry*. (2020) 11:459. doi: 10.3389/fpsyt.2020.00845
33. Khasawneh AI, Humeidan AA, Alsulaiman JW, Bloukh S, Ramadan M, Al-Shatanawi TN, et al. Medical students and COVID-19: knowledge, attitudes, and precautionary measures. a descriptive study from Jordan. *Front Public Health*. (2020) 8:253. doi: 10.3389/fpubh.2020.00253
34. Meo SA, Abukhalaf AA, Alomar AA, Sattar K, Klonoff DC. COVID-19 Pandemic: impact of quarantine on medical students' mental wellbeing and learning behaviors. *Pak J Med Sci*. (2020) 36:S43–8. doi: 10.12669/pjms.36.COVID19-S4.2809

35. Abbasi S, Ayoob T, Malik A, Memon SI. Perceptions of students regarding E-learning during Covid-19 at a private medical college. *Pak J Med Sci*. (2020) 36:S57–61. doi: 10.12669/pjms.36.COVID19-S4.2766
36. Sethi BA, Sethi A, Ali S, Aamir HS. Impact of Coronavirus disease (COVID-19) pandemic on health professionals. *Pak J Med Sci*. (2020) 36:S6–S11. doi: 10.12669/pjms.36.COVID19-S4.2779
37. Ikhlaq A, Bint-E-Riaz H, Bashir I, Ijaz F. Awareness and attitude of undergraduate medical students towards 2019-novel corona virus. *Pak J Med Sci*. (2020) 36:S32–6. doi: 10.12669/pjms.36.COVID19-S4.2636
38. Lin Y, Hu Z, Alias H, Wong LP. Influence of mass and social media on psychobehavioral responses among medical students during the downward trend of COVID-19 in Fujian, China: cross-sectional study. *J Med Internet Res*. (2020) 22:e19982. doi: 10.2196/19982
39. Choi B, Jegatheeswaran L, Minocha A, Alhilani M, Nakhoul M, Mutengesa E. The impact of the COVID-19 pandemic on final year medical students in the United Kingdom: a national survey. *BMC Med Educ*. (2020) 20:206. doi: 10.1186/s12909-020-02117-1
40. Çalişkan F, Midik Ö, Baykan Z, Senol Y, Tanriverdi EÇ, Tengiz FI, et al. The knowledge level and perceptions toward COVID-19 among Turkish final year medical students. *Postgraduate Med*. doi: 10.1080/00325481.2020.1795486. [Epub ahead of print].
41. Termorshuizen JD, Watson HJ, Thornton LM, Borg S, Flatt RE, MacDermod CM, et al. Early impact of COVID-19 on individuals with self-reported eating disorders: a survey of ∼1,000 individuals in the United States and the Netherlands. *Int J Eat Disord*. (2020). doi: 10.1002/eat.23353. [Epub ahead of print].
42. Akers A, Blough C, Iyer MS. COVID-19 implications on clinical clerkships and the residency application process for medical students. *Cureus*. (2020) 12:e7800. doi: 10.7759/cureus.7800
43. Rose S. Medical student education in the time of COVID-19. *JAMA*. (2020) 323:2131–2. doi: 10.1001/jama.2020.5227
44. Association of American Medical Colleges (AAMC). *Important Guidance for Medical Students on Clinical Rotations During the Coronavirus (COVID-19) Outbreak*. AAMC (2020). Available online at: https://www.aamc.org/news-insights/press-releases/important-guidance-medical-students-clinical-rotations-during-coronavirus-covid-19-outbreak (accessed July 31, 2020).
45. Zou D. *COVID-19: Implications for Medical Students*. The Medical Journal of Australia (2020). Available online at: https://insightplus.mja.com.au/2020/12/covid-19-implications-for-medical-students/ (accessed July 31, 2020).
46. Dedeilia A, Sotiropoulos MG, Hanrahan JG, Janga D, Dedeilias P, Sideris M. Medical and surgical education challenges and innovations in the covid-19 era: a systematic review. *In Vivo*. (2020) 34(Suppl. 3):1603–11. doi: 10.21873/invivo.11950
47. Franchi T. The impact of the covid-19 pandemic on current anatomy education and future careers: a student's perspective. *Anat Sci Educ*. (2020) 13:312–5. doi: 10.1002/ase.1966
48. Kapila AK, Schettino M, Farid Y, Ortiz S, Hamdi M. The impact of coronavirus disease 2019 on plastic surgery training: the resident perspective. *Plast Reconstr Surg Glob Open*. (2020) 8:e3054. doi: 10.1097/GOX.0000000000003054
49. Mian A, Khan S. Medical education during pandemics: a UK perspective. *BMC Med*. (2020) 18:100. doi: 10.1186/s12916-020-01577-y
50. Kaparounaki CK, Patsali ME, Mousa D-PV, Papadopoulou EVK, Papadopoulou KKK, Fountoulakis KN. University students' mental health amidst the COVID-19 quarantine in Greece. *Psychiatry Res*. (2020) 290:113111. doi: 10.1016/j.psychres.2020.113111
51. Suwalska J, Suwalska A, Szczygieł M, Łojko D. Medical students and stigma of depression. Part 2. Self-stigma. *Psychiatr Pol*. (2017) 51:503–13. doi: 10.12740/PP/OnlineFirst/67373
52. Usher K, Bhullar N, Jackson D. Life in the pandemic: social isolation and mental health. *J Clin Nurs*. (2020) 29:2756–7. doi: 10.1111/jocn.15290
53. Phillipou A, Meyer D, Neill E, Tan EJ, Toh WL, Van Rheenen TE, et al. Eating and exercise behaviors in eating disorders and the general population during the COVID-19 pandemic in Australia: initial results from the COLLATE project. *Int J Eat Disord*. (2020) 53:1158–65. doi: 10.1002/eat.23317
54. Jahrami H, Sater M, Abdulla A, Faris MeA-I, AlAnsari A. Eating disorders risk among medical students: a global systematic review and meta-analysis. *Eat Weight Disord*. (2019) 24:397–410. doi: 10.1007/s40519-018-0516-z
55. Fernández-Aranda F, Casas M, Claes L, Bryan DC, Favaro A, Granero R, et al. COVID-19 and implications for eating disorders. *Eur Eat Disord Rev*. (2020) 28:239–45. doi: 10.1002/erv.2738
56. Touyz S, Lacey H, Hay P. Eating disorders in the time of COVID-19. *J Eat Disord*. (2020) 8:19. doi: 10.1186/s40337-020-00295-3
57. UNESCO. *Universities tackle the impact of COVID-19 on disadvantaged students Paris, France*. (2020). Available online at: https://en.unesco.org/news/universities-tackle-impact-covid-19-disadvantaged-students (accessed July 31, 2020).
58. Pather N, Blyth P, Chapman JA, Dayal MR, Flack NAMS, Fogg QA, et al. Forced disruption of anatomy education in Australia and New Zealand: an acute response to the covid-19 pandemic. *Anat Sci Educ*. (2020) 13:284–300. doi: 10.1002/ase.1968
59. Aghakhani K, Shalbafan M. What COVID-19 outbreak in Iran teaches us about virtual medical education. *Med Educ Online*. (2020) 25:1770567. doi: 10.1080/10872981.2020.1770567
60. Sahi PK, Mishra D, Singh T. Medical education amid the COVID-19 pandemic. *Indian Pediatr*. (2020) 57:652–7. doi: 10.1007/s13312-020-1894-7
61. Najibi S, Carney PA, Thayer EK, Deiorio NM. Differences in coaching needs among underrepresented minority medical students. *Fam Med*. (2019) 51:516–22. doi: 10.22454/FamMed.2019.100305
62. Low D, Pollack SW, Liao ZC, Maestas R, Kirven LE, Eacker AM, et al. Racial/ethnic disparities in clinical grading in medical school. *Teach Learn Med*. (2019) 31:487–96. doi: 10.1080/10401334.2019.1597724
63. Hill KA, Samuels EA, Gross CP, Desai MM, Sitkin Zelin N, Latimore D, et al. Assessment of the prevalence of medical student mistreatment by sex, race/ethnicity, and sexual orientation. *JAMA Intern Med*. (2020) 180:653–65. doi: 10.1001/jamainternmed.2020.0030
64. Ajilore O, Thames AD. The fire this time: the stress of racism, inflammation and COVID-19. *Brain Behav Immun*. (2020) 88:66–7. doi: 10.1016/j.bbi.2020.06.003
65. Dubey S, Biswas P, Ghosh R, Chatterjee S, Dubey MJ, Chatterjee S, et al. Psychosocial impact of COVID-19. *Diabetes Metab Syndr*. (2020) 14:779–88. doi: 10.1016/j.dsx.2020.05.035
66. Rzymski P, Nowicki M. COVID-19-related prejudice toward Asian medical students: a consequence of SARS-CoV-2 fears in Poland. *J Infect Public Health*. (2020) 13:873–6. doi: 10.1016/j.jiph.2020.04.013
67. Kmietowicz Z. Are medical schools turning a blind eye to racism? *BMJ*. (2020) 368:m420. doi: 10.1136/bmj.m420
68. Rosa WE, Shook A, Acquaviva KD. LGBTQ+ inclusive palliative care in the context of COVID-19: pragmatic recommendations for clinicians. *J Pain Symptom Manage*. (2020) 60:e44–7. doi: 10.1016/j.jpainsymman.2020.04.155
69. Bupa. *Mental Wellbeing Survey of Prospective International and Overseas Students*. (2019). Available online at: https://aiec.idp.com/uploads/AIEC_2019/Proceedings/AIEC2019_231_1013_Tomyn_Ngyen.pdf (accessed July 31, 2020).
70. Sahu P. Closure of universities due to coronavirus disease 2019 (COVID-19): impact on education and mental health of students and academic staff. *Cureus*. (2020) 12:e7541. doi: 10.7759/cureus.7541
71. Australian Government Department of Health. *Coronavirus (COVID-19) Advice for Travellers: Commonwealth of Australia*. (2020). Available online at: https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/coronavirus-covid-19-advice-for-travellers (accessed July 31, 2020).
72. Zhang J, Paksarian D, Lamers F, Hickie IB, He J, Merikangas KR. Sleep patterns and mental health correlates in US adolescents. *J Pediatr*. (2017) 182:137–43. doi: 10.1016/j.jpeds.2016.11.007
73. Smith CA. Covid-19: healthcare students face unique mental health challenges. *BMJ*. (2020) 369:m2491. doi: 10.1136/bmj.m2491
74. Zhai Y, Du X. Mental health care for international Chinese students affected by the COVID-19 outbreak. *Lancet Psychiatry*. (2020) 7:e22. doi: 10.1016/S2215-0366(20)30089-4
75. Bentata Y. The COVID-19 pandemic and international federation of medical students' association exchanges: thousands of students deprived

of their clinical and research exchanges. *Med Educ Online*. (2020) 25:1783784. doi: 10.1080/10872981.2020.1783784
76. Parisi MCR, Frutuoso L, Benevides SSN, Barreira NHM, Silva JLG, Pereira MC, et al. The challenges and benefits of online teaching about diabetes during the COVID-19 pandemic. *Diabetes Metab Syndr*. (2020) 14:575–6. doi: 10.1016/j.dsx.2020.04.043
77. Khadjooi K, Scott P, Jones L. What is the impact of pregnancy and parenthood on studying medicine? Exploring attitudes and experiences of medical students. *J R Coll Physicians Edinb*. (2012) 42:106–10. doi: 10.4997/JRCPE.2012.203
78. Arowoshola L. Medical education engagement during the COVID-19 era–a student parents perspective. *Med Educ Online*. (2020) 25:1788799. doi: 10.1080/10872981.2020.1788799
79. Klasen JM, Vithyapathy A, Zante B, Burm S. "The storm has arrived": the impact of SARS-CoV-2 on medical students. *Perspect Med Educ*. (2020) 9:181–5. doi: 10.1007/s40037-020-00592-2
80. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system REsilience PROGRAM (REPROGRAM) international consortium (part 2). *Front Public Health*. (2020) 8:410. doi: 10.3389/fpubh.2020.00410
81. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine across the globe - position paper from the COVID-19 pandemic health system resilience PROGRAM (REPROGRAM) international consortium (Part 1). *Front Public Health*. (2020) 8:1–15. doi: 10.3389/fpubh.2020.556720
82. Bhaskar S, Bradley S, Sakhamuri S, Moguilner S, Chattu VK, Pandya S, et al. Designing futuristic telemedicine using artificial intelligence and robotics in the COVID-19 era. *Front Public Health*. (2020) 8:556789. doi: 10.3389/fpubh.2020.556789
83. Bhaskar S, Sinha A, Banach M, Mittoo S, Weissert R, Kass JS, et al. Cytokine storm in COVID-19—immunopathological mechanisms, clinical considerations, and therapeutic approaches: the REPROGRAM consortium position paper. *Front Immunol*. (2020) 11:1648. doi: 10.3389/fimmu.2020.01648
84. Ruthberg JS, Quereshy HA, Ahmadmehrabi S, Trudeau S, Chaudry E, Hair B, et al. A multimodal multi-institutional solution to remote medical student education for otolaryngology during COVID-19. *Otolaryngol Head Neck Surg*. (2020) 163:707–9. doi: 10.1177/0194599820933599
85. Moszkowicz D, Duboc H, Dubertret C, Roux D, Bretagnol F. Daily medical education for confined students during coronavirus disease 2019 pandemic: a simple videoconference solution. *Clin Anat*. (2020) 33:927–8. doi: 10.1002/ca.23601
86. Singh K, Srivastav S, Bhardwaj A, Dixit A, Misra S. Medical education during the COVID-19 pandemic: a single institution experience. *Indian Pediatr*. (2020) 57:678–9. doi: 10.1007/s13312-020-1899-2
87. Hoopes S, Pham T, Lindo FM, Antosh DD. Home surgical skill training resources for obstetrics and gynecology trainees during a pandemic. *Obstet Gynecol*. (2020) 136:56–64. doi: 10.1097/AOG.0000000000003931
88. Chandratre S. Medical students and COVID-19: challenges and supportive strategies. *J Med Educ Curric Dev*. (2020) 7:2382120520935059. doi: 10.1177/2382120520935059
89. Lapolla P, Mingoli A. COVID-19 changes medical education in Italy: will other countries follow? *Postgrad Med J*. (2020) 96:375. doi: 10.1136/postgradmedj-2020-137876
90. Wang JHS, Tan S, Raubenheimer K. Rethinking the role of senior medical students in the COVID-19 response. *Med J Aust*. (2020) 212:490.e1. doi: 10.5694/mja2.50601
91. Australian Medical Students Association (AAMC). *Coronavirus (Covid-19) Medical Student Public Hospital Engagement Contract Offer Checklist*. AAMC (2020). Available online at: https://ama.com.au/article/COVID_19_Medical_Student_Public_Hospital_Engagement (accessed July 31, 2020).
92. Sandhu P, de Wolf M. The impact of COVID-19 on the undergraduate medical curriculum. *Med Educ Online*. (2020) 25:1764740. doi: 10.1080/10872981.2020.1764740
93. Zaed I. COVID-19 consequences on medical students interested in neurosurgery: an Italian perspective. *Br J Neurosurg*. doi: 10.1080/02688697.2020.1777260. [Epub ahead of print].
94. Boodman C, Lee S, Bullard J. Idle medical students review emerging COVID-19 research. *Med Educ Online*. (2020) 25:1770562. doi: 10.1080/10872981.2020.1770562
95. Sklar DP. COVID-19: lessons from the disaster that can improve health professions education. *Acad Med*. (2020) 95:1631–3. doi: 10.1097/ACM.0000000000003547
96. Ashcroft J, Byrne MHV, Brennan PA, Davies RJ. Preparing medical students for a pandemic: a systematic review of student disaster training programmes. *Postgrad Med J*. (2020). doi: 10.1136/postgradmedj-2020-137906. [Epub ahead of print].
97. Iancu AM, Kemp MT, Alam HB. Unmuting medical students' education: utilizing telemedicine during the COVID-19 pandemic and beyond. *J Med Internet Res*. (2020) 22:e19667. doi: 10.2196/19667
98. Singal A, Bansal A, Chaudhary P. Cadaverless anatomy: darkness in the times of pandemic Covid-19. *Morphologie*. (2020) 104:147–50. doi: 10.1016/j.morpho.2020.05.003
99. Dawidziuk A, Gandhewar R. Preparing medical students for global challenges beyond COVID-19. *Health Sci Rep*. (2020) 3:e162. doi: 10.1002/hsr2.162
100. Roll R, Chiu M, Huang C. Answering the call to action: COVID-19 curriculum design by students for students. *Acad Med*. (2020) 95:e6. doi: 10.1097/ACM.0000000000003588
101. Bond KS, Jorm AF, Kitchener BA, Reavley NJ. Mental health first aid training for Australian medical and nursing students: an evaluation study. *BMC Psychol*. (2015) 3:11. doi: 10.1186/s40359-015-0069-0
102. Davies EB, Beever E, Glazebrook C. A pilot randomised controlled study of the mental health first aid eLearning course with UK medical students. *BMC Med Educ*. (2018) 18:45. doi: 10.1186/s12909-018-1154-x
103. Australian Goverment Department of Health. *Mental Health First Aid Training for Medical Students*. Commonwealth of Australia (2020). Available online at: https://www.health.gov.au/ministers/the-hon-greg-hunt-mp/media/mental-health-first-aid-training-for-medical-students (accessed July 31, 2020).
104. Finn GM, Brown MEL, Laughey W, Dueñas A. #pandemicpedagogy: using twitter for knowledge exchange. *Med Educ*. (2020). doi: 10.1111/medu.14242. [Epub ahead of print].
105. American College of Surgeons (ACS). *Medical Student Core Curriculum Chicago: American College of Surgeons*. (2020). Available online at: https://www.facs.org/education/program/core-curriculum?fbclid=IwAR2Sb7rSQ7MZHtCEPfRxiKTgg_1JaIZ9zynu5XozzgA53TSPs7pi63qAUKQ (accessed July 31, 2020).
106. Haines MJ, Yu ACM, Ching G, Kestler M. Integrating a COVID-19 volunteer response into a year-3 md curriculum. *Med Educ*. (2020) 54:960–1. doi: 10.1111/medu.14254
107. Miller DG, Pierson L, Doernberg S. The role of medical students during the COVID-19 pandemic. *Ann Intern Med*. (2020) 173:145–6. doi: 10.7326/M20-1281
108. Cerqueira-Silva T, Carreiro R, Nunes V, Passos L, Canedo B, Andrade S, et al. *Bridging Learning in Medicine and Citizenship During the COVID-19 Pandemic: A Telehealth-Based Strategy*. (2020). Available online at: https://ssrn.com/abstract=3625871 (accessed July 31, 2020).
109. Santos JJ, Chang DD, Robbins KK, Cam EL, Garbuzov A, Miyakawa-Liu M, et al. Answering the call: medical students reinforce health system frontlines through ochsner COVID-19 hotline. *Ochsner J*. (2020) 20:144. doi: 10.31486/toj.20.0065
110. Abedi M, Abedi D. A letter to the editor: the impact of COVID-19 on intercalating and non-clinical medical students in the UK. *Med Educ Online*. (2020) 25:1771245. doi: 10.1080/10872981.2020.1771245
111. Rastegar Kazerooni A, Amini M, Tabari P, Moosavi M. Peer mentoring for medical students during the COVID-19 pandemic via a social media platform. *Med Educ*. (2020) 54:762–3. doi: 10.1111/medu.14206
112. Huddart D, Hirniak J, Sethi R, Hayer G, Dibblin C, Meghna Rao B, et al. #MedStudentCovid: how social media is supporting students during COVID-19. *Med Educ*. (2020) 54:951–2. doi: 10.1111/medu.14215
113. Roberts V, Malone K, Moore P, Russell-Webster T, Caulfield R. Peer teaching medical students during a pandemic. *Med Educ Online*. (2020) 25:1772014. doi: 10.1080/10872981.2020.1772014

114. Australian Medical Association Limited. *New Free, Confidential Mental Health Counselling Service for Doctors and Medical Students.* (2020). Available online at: https://ama.com.au/gp-network-news/new-free-confidential-mental-health-counselling-service (accessed July 31, 2020).
115. NHS. *Support Now: NHS Leadership Academy.* (2020). Available online at: https://people.nhs.uk/help/ (accessed July 15, 2020).
116. Project5.org. *Access Support-for NHS Staff.* (2020). Available online at: https://www.project5.org/getsupport (accessed July 31, 2020).
117. Canadian Medical Association. *Support Line.* (2020). Available online at: https://www.cma.ca/supportline (accessed July 15, 2020).
118. Physician Health Program. *Physician Health Program of British Columbia.* (2020). Available online at: https://www.physicianhealth.com/about-us (accessed July 15, 2020).
119. Quebec Physicians' Health Program (PAMQ). *PAMQ.* (2020). Available online at: http://www.pamq.org/en (accessed July 15, 2020).
120. Alberta Medical Association. *Physician and Family Support Program: Alberta Medical Association.* (2020). Available online at: https://www.albertadoctors.org/services/pfsp (accessed July 31, 2020).
121. Indian Medical Association. *IMA*. (2020). Available online at: https://www.ima-india.org/ima/index.php (accessed July 31, 2020).
122. Physician Support Line USA. *United States of America: Physician Support Line.* (2020). Available online at: https://www.physiciansupportline.com/ (accessed July 31, 2020).
123. Howell AN, Rheingold AA, Uhde TW, Guille C. Web-based CBT for the prevention of anxiety symptoms among medical and health science graduate students. *Cogn Behav Ther*. (2019) 48:385–405. doi: 10.1080/16506073.2018.1533575
124. Huang J, Nigatu YT, Smail-Crevier R, Zhang X, Wang J. Interventions for common mental health problems among university and college students: a systematic review and meta-analysis of randomized controlled trials. *J Psychiatr Res*. (2018) 107:1–10. doi: 10.1016/j.jpsychires.2018.09.018
125. Lattie EG, Kashima K, Duffecy JL. An open trial of internet-based cognitive behavioral therapy for first year medical students. *Internet Interv*. (2019) 18:100279. doi: 10.1016/j.invent.2019.100279
126. Service NSW. (2020). International student COVID-19 crisis accommodation–guidelines. Available online at: https://www.service.nsw.gov.au/international-student-covid-19-crisis-accommodation-guidelines (accessed July 1, 2020).
127. Binder R, Garcia P, Johnson B, Fuentes-Afflick E. Sexual harassment in medical schools: the challenge of covert retaliation as a barrier to reporting. *Acad Med*. (2018) 93:1770–3. doi: 10.1097/ACM.0000000000002302

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BRIEF RESEARCH REPORT
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Staying Connected: Reaching Out to Psychiatric Patients During the Covid-19 Lockdown Using an Online Blog

Astrid Lehner, Klaus Nuißl, Winfried Schlee and Berthold Langguth*

Department for Psychiatry and Psychotherapy, University of Regensburg, Regensburg, Germany

Health systems worldwide are challenged by the coronavirus pandemic and all medical specialties have struggle to meet the conflicting requirements for virus containment on the one hand and treatment of other medical conditions on the other. This holds true also for psychiatry. *Per se*, psychiatric patients are highly vulnerable to suffer from social isolation and loneliness. As a result of the Covid-19 pandemic and lockdown measures, unfortunately, this vulnerability is even further increased. As a part of its pandemic risk management, the outpatient clinic of the Psychiatric District Hospital Regensburg launched an online blog as a means of assisting patients who were required to stay home. Aim of the blog was to stay by patients' side in those uncertain times by offering an online connection to their therapists, by providing important information about the pandemic situation, by offering some ideas on how to build a daily routine and how to meaningfully spend their time at home during the lockdown. We also aimed at involving patients as experts in their own affairs by inviting them to contribute to the blog's shape and content. As a result of coordinated team effort, it was possible to launch a blog within few days, and this was perceived helpful by many patients. Overall, however, patient involvement turned out to be a challenge requiring more attention in future work.

Keywords: SARS-CoV-2, COVID-19, corona virus, clinical psychiatry, pandemic, e-health, citizen involvement, experienced involvement

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****Correspondence:***
Astrid Lehner
astrid.lehner@medbo.de

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INTRODUCTION

In order to slow down the rapid spread of SARS-CoV-2, many countries worldwide have to face restrictions in public and private life. For health care professionals and hospitals, this implies the challenge of balancing preventive measures to stop the spread of the virus and, at the same time, address the needs of patients suffering from other medical conditions.

Patients with serious psychiatric illness are known to be particularly vulnerable during crises of health care systems (1, 2). Recently, it has been shown that patients with mental disorders do have an increased risk of Covid-19 infection and mortality (3). There have already been some suggestions on how to manage in- and outpatient units during the pandemic in order to provide the best possible treatment (2, 4). For outpatient treatment, this includes the limitation of face-to-face appointments and the shift toward telemedicine wherever possible (5, 6).

As psychiatry is mostly based on verbal, paraverbal and nonverbal communication and less on analytical tests or physical examination, video or telephone appointments are easier to accomplish

in psychiatry compared to many other medical professions (7). Furthermore, the repertoire of telemedicine is expanded by a growing amount of online programs and apps offering support for patients suffering from mental illness (8). In the last decade, telemedicine has been increasingly examined in outpatient care of psychiatric patients and has been shown to have comparable outcomes as in-person treatment e.g., for patients suffering from depression (9). Telemedicine has also been shown to improve clinical outcomes for patients suffering from post-traumatic stress disorder by supporting them to initiate and ideally complete evidence-based psychotherapy (10). Furthermore, telemedicine enables continuous psychiatric care for patients from more rural areas who might otherwise not be able to attend appointments on a regular basis (11).

With respect to the Covid-19 pandemic, telepsychiatry has been reported to be well-accepted by patients during phases of public lockdown (12). It involves phone calls and video-based appointments both of which are able to compensate for one-to-one contacts between patients and health care professionals.

However, pandemic risk management often includes the complete shutdown of group therapies (4), an important part of psychiatric treatment. It is much more complicated to cover those group activities by phone or video calls due to technical challenges and digital privacy protection issues. Consequently, in many cases, those therapies are paused without replacement during phases of lockdown. This applies e.g., to occupational therapy, sports therapy or musical therapies, often an integral part of patients' daily routines, especially when suffering from severe or chronic psychiatric conditions. Many of those patients live socially isolated and have difficulties keeping a stable daily routine in general, and during public lockdown in particular, increasing the risk of symptom deterioration.

Corona risk management in the Psychiatric District Hospital Regensburg, Germany, also included the reduction of such group activities for inpatients and the complete cancellation of group therapies for outpatients (13). As patients reported facing problems staying at home and feeling deserted by their health care professionals, therapists from the outpatient clinic joined forces with patient representatives and the hospital's Public Relations department to launch a patient-centered online Blog as an add-on to phone-calls and video-meetings. Aim of the blog was to make patients feel connected to the clinic and their therapists, to provide them with some ideas on how to build a daily routine and how to meaningfully spend their time at home in those uncertain times. We also tried involving patients as experts in their own affairs, with the objective to allow them to contribute to and shape the blog's content. A colleague with a degree in "experienced involvement," a German training for peer support, was involved in implementing the blog. Peer support has been shown to improve self-efficacy, sense of hope and quality of life of patients with mental disorders (14, 15).

METHODS

Through this paper, we provide information about the launching and content of the blog and about adjustments we had to make. In addition, the total number of page views will be reported. Only page views from outside the clinic are counted, i.e., page views inside the clinic's network were'nt taken into consideration. Furthermore, mean page views on working days (Monday to Friday) were compared with mean page views on the weekend using an unpaired *t*-test. IBM SPSS Statistics 24 (IBM Corporation, Armonk, NY) was used for data analyses.

The main target group of the blog was a subgroup of the clinic's outpatients. The outpatient department serves over 8,000 patients/year. However, the blog targeted primarily patients, who suffer from chronic psychiatric disorders such as affective disorders, schizophrenia or personality disorders, and who receive regular multidisciplinary treatment in our outpatient clinic. This group comprises about 300 patients. As the information about the establishment of the blog were communicated through many different channels, it is very difficult to estimate, how well we reached the target group and how many more patients received the information. As the blog was open to the public and could therefore be used and read by anyone interested, the users of the blog are hereinafter referred to as "readers" instead of "patients."

Furthermore, readers' feedback will be reported including feedback given during phone calls or by email, as well as feedback provided during an online survey. Readers were continuously encouraged to write emails in case of questions or ideas concerning the blog. After 7 weeks of blog activity, we asked for readers' wellbeing and their feedback in an anonymous online survey that was approved by the Ethics Committee of the University Hospital of Regensburg, Germany (reference number 20-1862-101). In order to facilitate the survey, there was an explanatory blog post, also providing the link to the questionnaire. Thereby, we ensured that only blog readers could participate in the survey. The survey was generated and launched using the services of www.soscisurvey.de.

In this survey, we asked for readers' age, gender, place of residence, current or past experience of a psychiatric illness and whether the reader had been under medical treatment in the Psychiatric District Hospital Regensburg. Furthermore, a modified version of the Clinical Global Impression (16) was used to enquire about any changes in subjective clinical global impression of somatic and mental wellbeing in comparison to before the beginning of lockdown measures (from 1 = much better to 7 = much worse) and for unexpected improvements or impairment in everyday life due to public lockdown. With respect to the blog, we asked (a) for how many weeks the blog had already been known by the reader, (b) for how many weeks the blog was actively read, (c) how useful the blog was perceived to be, (d) how often the blog was visited, (e) how often the new articles were read and, (f) how often information and tips were actively transferred into everyday life. Finally, we asked which aspects of the blog were perceived as being useful. The readers' feedback will be presented descriptively.

RESULTS

Blog Content

The blog comprised two categories: The first category contained general information about the Covid-19 pandemic and rules

of conduct, as well as tips for everyday life. For instance, there was a video on face masks, links to reliable sources of information regarding the coronavirus pandemic and a blog post on how to explain the current situation to children. These articles could be read anytime. The second category consisted of two articles per day providing tips given by different professions: psychotherapeutic tips, mindfulness, recovery, occupational therapy, healthy and easy recipes, ideas for home workouts, musical therapy and positive news. Furthermore, we tried to foster peer support by asking patients what was helpful for them during their daily life in this period of lockdown. The incoming information was then shared anonymously on the blog.

The articles consisted of written information, links to online resources and amateur audios and videos created by the clinic's health care staff. As many of the regular treatment offers paused, it was possible for the staff to invest a certain amount of time for producing blog content. Thereby, it was ensured that patients saw familiar faces and heard familiar voices in those uncertain times, whilst staying at home. Additionally, readers could write an email if they had questions with respect to the content of the articles.

There were two new articles per day from Monday to Friday, published on 9:00 a.m. and 3:00 p.m. These articles could only be retrieved for 1 h (i.e., until 10:00 a.m. and 4:00 p.m., respectively) in order to provide a certain daily routine. On Saturdays, there was one article at 3:00 p.m. On Sundays and bank holidays, there were no regular articles published.

Timeline and Adjustments

On March 20, 2020, a partial lockdown was announced in Bavaria, Germany, due to the corona pandemic, leading to a rapid shutdown of the outpatient unit of the Psychiatric District Hospital Regensburg (13). Within 10 days, the online blog "Bleib Zuhause" (German for "Stay at home") (www.medbo.de/bleibzuhause) was launched with its first article being published on March 30 2020. On the first days, informative articles were published containing information about reliable sources of information concerning Covid-19, about rules of conduct for everyday life in order to stop the rapid spread of the virus, about face masks and current procedures within the hospital. On April 3, 2020, the regular blog activity started, presenting two articles per day. After 10 days, the 1-h-limit of article availability was changed, as it turned out to be too short for the blog's readers. From then on, all articles were visible for the whole day of their publication. From May 25, 2020 to June 1, 2020, the feedback survey was online. After relaxation of the lockdown measures, blog activity was reduced to one article per working day, from June 2, 2020 onwards. On July 1, 2020, the blog was stopped for a summer break.

Announcement of the Blog

In order to inform patients about the launching of the blog, it was mentioned in scheduled phone calls. In addition, flyers and posters were printed and made available. Flyers were also added to regular mail to patients (e.g., prescriptions). Additionally, local newspapers and local TV and radio stations reported on the blog in order to bring the news to its potential recipients.

TABLE 1 | Mean page views per weekday.

	Mean page views ± standard deviation
Monday	166.31 ± 147.37
Tuesday	166.85 ± 148.34
Wednesday	150.69 ± 95.36
Thursday	140.62 ± 102.27
Friday	150.85 ± 149.89
Saturday	100.77 ± 95.56
Sunday	74.54 ± 74.72

Page Views

Overall, the blog was viewed 12.358 times from April 1, 2020 to June 30, 2020. There were a mean of 135.80 page views per day. The blog was mostly viewed from Monday to Friday with least views on Sunday (see **Table 1**). The unpaired t-test comparing page views on weekdays (155.06 ± 127.20) with page views on weekends (87.65 ± 85.10) showed a statistically significant difference [$t(89) = 2.485$; $p = 0.015$]. In **Figure 1**, mean page views for all 13 weeks during which the blog was online, are depicted.

Results of the Online Survey and Patient Feedback

Ten readers answered the survey, nine of them being female. All reported to have experienced psychiatric illness before. All of them had been under medical treatment in the Psychiatric District Hospital Regensburg and also lived within the area served by the hospital. The change of clinical subjective global impression can be found in **Table 2**.

Reasons for worsening were social isolation, weight gain, worsening of pain due to missing physiotherapy and the need to wear a face mask. Reasons for improvement were going for a walk more frequently (going for a walk individually was allowed in Bavaria at all times), unexpected support by others and stress reduction.

With respect to the blog, seven of ten readers knew and read the blog from the very beginning. Six readers said the blog was helpful or very helpful, three said it was "neutral," one did not answer the question. The frequency of blog visits, reads and active usage of the content is summarized in **Table 3**. When asked about useful aspects of the blog, readers named relaxation techniques, variety of content as well as the knowledge that "someone is interested in me and my need for support."

Outside of the survey, some patients told us in phone calls or emails that the blog was like an Advent calendar for them, triggering positive feelings like curiosity and pleasant anticipation about the content that might be online next. All in all, however, the option to write an email if there were questions, comments or feedback concerning the blog content was scarcely used.

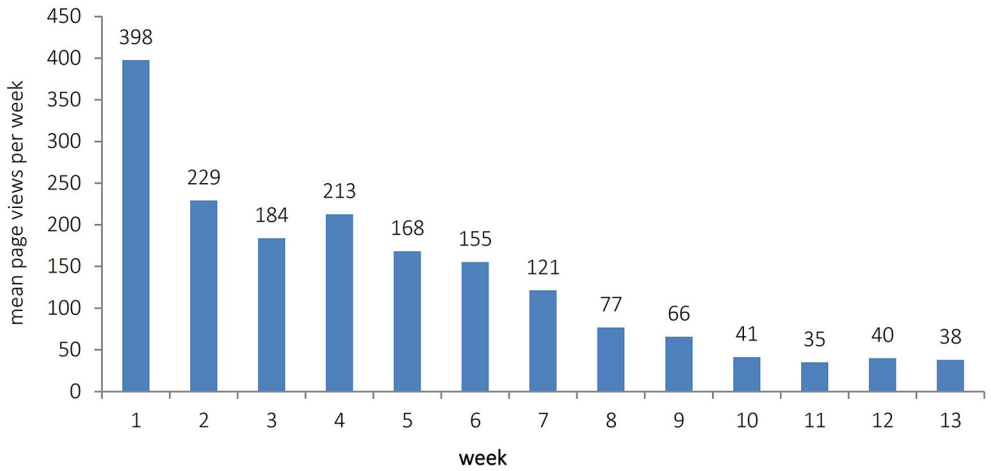

FIGURE 1 | Mean page views for all 13 weeks, in which the blog was online.

DISCUSSION

In times of the covid-19 pandemic, there is increasing awareness of the possibilities and advantages telemedicine has to offer: it helps protecting hospitals, vulnerable patient groups and health care professionals alike by limiting direct interpersonal contact (17). Furthermore, telemedicine ensures treatment continuity for chronically ill patients even in times of public lockdown (18). While telemedicine is mostly used in terms of phone or video calls, there are many additional resources which might be useful especially in times of a pandemic. There are many mental health-related websites known to be used by psychiatric patients (19). Therefore, there have already been ideas about telehealth services which support patients in their use of such online resources (20). In addition, there are many online blogs on different psychiatric diagnoses or on mental health in general written by patients themselves, psychiatrists or e.g., the American Psychiatric Association (APA) (21). Those blogs mainly contain individual reports on mental illness and recovery or general content on psychoeducation and current research. A huge advantage of blogs is their broader audience (21): Many patients are able to read, use and benefit from the same blog post. As blog posts can be read anonymously, being at home without anybody watching, patients may also be more willing and able to deal with the provided content in more depth; or experiment with exercises they would feel embarrassed about in the presence of others. On the other hand, only few blogs contain scientifically sound information. Moreover, in most cases blogs are written by authors that patients do not know and with whom they have no direct personal relationship. Our approach set out to combine the possibility of reaching a broader audience, i.e., the clinic's patients as a whole, as well as providing content by authors that patients already knew from their usual treatment sessions and with whom there already existed a therapeutic relationship. Content could be used in addition to personal or tele-appointments by providing e.g., current information, psychoeducation, tutorials for exercises or ideas for daily healthcare routines.

TABLE 2 | Change of clinical subjective global impression in comparison to pre-lockdown (simple frequency count; $n = 10$).

	Somatic wellbeing	Mental wellbeing
Very much better	0	1
Much better	0	0
Better	2	1
No change	3	2
Worse	4	5
Much worse	1	1
Very much worse	0	0

TABLE 3 | Frequency of blog usage (self-report by the readers).

	How often do you visit the blog?	How often do you read the current articles?	How often do you transfer the information and tips to your everyday life?
Twice a day	2	0	0
Daily	4	2	0
Every other day	3	6	3
Twice a week	0	1	3
Weekly	0	0	1
Less than once a week	0	0	2
Missing	1	1	1

The blog aimed at supporting patients suffering from chronic psychiatric disorders during public lockdown, by providing daily content from different therapeutic professions and thus helping to maintain a daily routine. It was used as an add-on to scheduled tele-appointments and was by no means meant to replace one-to-one-contact or regular therapies. Due to the rapid spread of coronavirus and the sudden need of support for mentally ill

patients who were instructed to stay at home, a quick start of the blog was given top priority.

There were both advantages and disadvantages implicated by the pressure of time that have to be kept in mind. The blog's content was created by the clinic's healthcare staff. An important advantage of this approach was that information was given by therapists that patients were already acquainted with from their regular treatment sessions, which might have fostered the feeling of still being connected despite the need to stay at home. Furthermore, it was hoped that ideas and tips from familiar healthcare staff might be taken seriously and therefore result in more active behavior than general tips found on the internet. However, these assumptions were not evaluated and have to be seen as hypotheses requiring future investigation. A disadvantage of having clinical staff create blog content was that obviously this was not their usual field of activity. Therefore, audios and videos produced could not meet professional standards but were of amateur quality. Furthermore, some efforts had to be made to win staff for the project within a few days. Some of them reacted with initial uncertainty concerning the creation of all-available online content that could be read by anyone interested. Nevertheless, many therapists were highly motivated to contribute to the blog since they felt a strong need to support their patients during the lockdown period. In order to address the existing uncertainties, it was especially important for the staff to (a) be thoroughly informed about the blog and about how the content will be used, (b) get technical support if needed for audio or video recordings, and (c) have free choice concerning the medium they desired to use: Some therapists decided against self-made videos in favor of text-based content including links to online-resources. After some blog articles had been published, the willingness to add content increased markedly, resulting in about 15–20 therapists from different disciplines contributing single or multiple articles to the blog.

A huge challenge was limited contact possibilities to patients during lockdown which made it hard to inform them about the launch of the blog. Of course, the blog was mentioned in scheduled phone calls. However, as many regular therapies had already stopped and phone calls could only cover a small amount of those therapies, many patients were not regularly contacted by the clinic within the first days of lockdown. Therefore, additional measures as stated above (flyers etc.) had to be taken to inform patients about the initiative. Additionally, it became clear that, although usually participating in the same therapy groups, patients were barely staying in contact with each other outside of treatment settings. Consequently, it was hardly spread by word of mouth or social media contacts between patients that the clinic offered the blog as support for everyone in need. Presumably the still existing stigma of psychiatric disorders prevents patients to share content in social media related to their role as a patient of a psychiatric clinic.

All in all, we realized that psychiatric patients are not well connected among each other by social media and it would have been much easier to reach patients if there had been a mailing-list with the permission to use it for such purpose.

With respect to page views, there were more views on weekdays than on weekends, which might mainly have been caused by the schedule of the blog (only one blog post on Saturdays and no new post on Sundays). On Sundays, only the archive containing informative blog posts was available. Consequently, an archive does not appear sufficient to reach patients on a daily basis in order to support them in their everyday routine. In this regard, very regular posts seem to be necessary.

The development of views in the course of time shows an initial peak of page views. In the first week, many efforts were made to inform patients about the blog's existence. As patients could not be contacted directly due to data protection issues, the news about the blog was spread using local radio and newspaper. Therefore, in the first week, many readers might have viewed the blog that were not necessarily part of its primary target group, i.e., individuals affected by chronic psychiatric illness. After about 4 weeks, a downward trend of page views started. This coincided with the time when in Bavaria, the partial lockdown was relaxed a bit and people were again allowed to leave their houses without cause. This and maybe a certain tiredness with respect to coronavirus-associated issues or a habituation to the situation may have gradually reduced the interest in online content.

We also experienced that patient feedback or ideas concerning the blog were hard to come by. Only 10 readers filled in the survey and only about 25 emails in total were written containing feedback, questions or suggestions concerning blog content. This may, at least in part, be due to characteristics of the patient group addressed: patients suffering from severe and/or chronic psychiatric conditions who might have little belief in their self-efficacy and who might not have been confident that their feedback was of real interest, or was able to change the blog's content. If asked during scheduled appointments, many patients gave very positive feedback with respect to the blog. We therefore assume that giving feedback online or via email was difficult for many patients – maybe as they did not know who exactly was receiving the message or maybe because of a fear to reveal sensible information by writing an email (i.e., coming out as someone who reads a blog for patients with psychiatric disorders). After all, the blog was conceptualized as an interactive project including both input from the clinic on the one side, and patient involvement on the other. We are still convinced that in phases of public restrictions and lockdown, offering a blog or some other form of interactive, low-threshold online-program including a lively exchange with and active involvement of patients would be desirable. However, as is already known from other forms of content on the internet, active reader involvement is not easy to accomplish and there is an urgent need for more sophisticated structures and tools to make patient involvement easier and more attractive. It may be of particular importance to offer tools which enable an anonymous, yet interactive, form of interaction. Thus, even if one would assume that the possibilities offered by the various forms of electronic communication might facilitate interaction among patients, patient empowerment and patient involvement, one has to realize that this might be more difficult to achieve for psychiatric disorders as compared to other chronic diseases. Therefore, the establishment of efficient communication structures for patient involvement in psychiatry presents a challenge that needs to be addressed in the future.

The little feedback on the blog considerably limits the conclusions that can be drawn from the added benefit the blog might have had on the regular treatment of patients during periods of lockdown. Nevertheless, the numbers of blog visits indicate that a considerable number of patients was reached during the time of restrictive anti-coronavirus measures. The authors are well aware about the limitations of this paper and the preliminary nature of the project. The blog was set up to address a suddenly arising need and with the aim to offer support for our patients as quickly as possible. We decided to aim for a publication of our experience with this project, hoping that everyone interested in supporting psychiatric patients in times of lockdown public health measures might benefit from our ideas and practical insights.

In sum, it was possible to launch a blog within few days, being supported by clinical staff, leading to positive patient feedback patients. Based on the daily visits, it can be assumed that the blog had a constant readership. Furthermore, different patients repeatedly reported that the feeling of the clinic still being interested in their wellbeing was an important and helpful message of the blog during the shutdown of much of public and private live. However, given the relatively limited feedback received, including a low response rate to the final online survey, we have to assume that only a small part of ideas and tips given in the blog were really translated into active behavior. Moreover, the blog didn't reach as many patients as was hoped, and overall, patient involvement turned out to be the most challenging part of the project. The blog did not generate its own considerable, interactive momentum, but lived from the clinic's input. Further development of this format including more sophisticated structures and tools will be necessary to make involvement by the target group more attractive.

As the blog was launched and operated by the clinic's health care staff who returned to full-time work after the end of the most restrictive lockdown measures, there were no resources anymore available to continue with the blog intensively. Therefore, it was not possible for the clinic to further improve and develop the format. In all, it's our hope that this paper will raise awareness for the situation of psychiatric patients during the Covid-19-pandemic and for the need for the development and improvement of low-threshold tele-health interventions for this particular patient group.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Universität Regensburg, Ethikkommission, D-93040 Regensburg. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

AL managed and coordinated the online blog, collected and analyzed data, wrote the manuscript. BL conceived of the present idea, supervised the project and contributed ideas to the online blog. KN introduced patients' perspective to the project. WS helped with project coordination and supervision of the project. All authors contributed ideas to the online blog, discussed the results and contributed to the final manuscript.

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REFERENCES

1. Druss BG. Addressing the COVID-19 pandemic in populations with serious mental illness. *JAMA Psychiatry.* (2020) 77:891–2. doi: 10.1001/jamapsychiatry.2020.0894
2. Kopelovich SL, Monroe-DeVita M, Buck BE, Brenner C, Moser L, Jarskog LF, et al. Community mental health care delivery during the COVID-19 pandemic: practical strategies for improving care for people with serious mental illness. *Community Ment Health J.* (2020) 1–11. doi: 10.1007/s10597-020-00662-z
3. Wang Q, Xu R, Volkow ND. Increased risk of COVID-19 infection and mortality in people with mental disorders: analysis from electronic health records in the United States. *World Psychiatry.* (2020). doi: 10.1002/wps.20806. [Epub ahead of print].
4. Starace F, Ferrara M. COVID-19 disease emergency operational instructions for Mental Health Departments issued by the Italian Society of Epidemiological Psychiatry. *Epidemiol Psychiatr Sci.* (2020) 29:e116. doi: 10.1017/S2045796020000372
5. Kavoor AR, Chakravarthy K, John T. Remote consultations in the era of COVID-19 pandemic: preliminary experience in a regional Australian public acute mental health care setting. *Asian J Psychiatr.* (2020) 51:102074. doi: 10.1016/j.ajp.2020.102074
6. O'Brien M, McNicholas F. The use of telepsychiatry during COVID-19 and beyond. *Ir J Psychol Med.* (2020) 1–6. doi: 10.1017/ipm.2020.54
7. Chan S, Parish M, Yellowlees P. Telepsychiatry today. *Curr Psychiatry Rep.* (2015) 17:89. doi: 10.1007/s11920-015-0630-9
8. Chan S, Godwin H, Gonzalez A, Yellowlees PM, Hilty DM. Review of use and integration of mobile apps into psychiatric treatments. *Curr Psychiatry Rep.* (2017) 19:96. doi: 10.1007/s11920-017-0848-9
9. Ruskin PE, Silver-Aylaian M, Kling MA, Reed SA, Bradham DD, Hebel JR, et al. Treatment outcomes in depression: comparison of remote treatment through telepsychiatry to in-person treatment. *Am J Psychiatry.* (2004) 161:1471–6. doi: 10.1176/appi.ajp.161.8.1471
10. Fortney JC, Pyne JM, Kimbrell TA, Hudson TJ, Robinson DE, Schneider R, et al. Telemedicine-based collaborative care for posttraumatic stress disorder: a randomized clinical trial. *JAMA Psychiatry.* (2015) 72:58–67. doi: 10.1001/jamapsychiatry.2014.1575
11. Fortney JC, Pyne JM, Turner EE, Farris KM, Normoyle TM, Avery MD, et al. Telepsychiatry integration of mental health

services into rural primary care settings. *Int Rev Psychiatry*. (2015) 27:525–39. doi: 10.3109/09540261.2015.1085838
12. Yellowlees P, Nakagawa K, Pakyurek M, Hanson A, Elder J, Kales HC. Rapid conversion of an outpatient psychiatric clinic to a 100% virtual telepsychiatry clinic in response to COVID-19. *Psychiatr Serv*. (2020) 71:749–52. doi: 10.1176/appi.ps.202000230
13. Kreuzer PM, Baghai TC, Rupprecht R, Wittmann M, Steffling D, Ziereis M, et al. SARS-CoV-2 risk management in clinical psychiatry: a few considerations on how to deal with an unrivaled threat. *Front Psychiatry*. (2020) 11:550. doi: 10.3389/fpsyt.2020.00550
14. Mahlke CI, Priebe S, Heumann K, Daubmann A, Wegscheider K, Bock T. Effectiveness of one-to-one peer support for patients with severe mental illness - a randomised controlled trial. *Eur Psychiatry*. (2017) 42:103–10. doi: 10.1016/j.eurpsy.2016.12.007
15. Davidson L, Bellamy C, Guy K, Miller R. Peer support among persons with severe mental illnesses: a review of evidence and experience. *World Psychiatry*. (2012) 11:123–8. doi: 10.1016/j.wpsyc.2012.05.009
16. Guy W. *ECDEU Assessment Manual for Psychopharmacology*. Rockville, MD: US Department of Heath, Education, and Welfare Public Health Service Alcohol, Drug Abuse, and Mental Health Administration (1976).
17. Klompas M. Coronavirus disease 2019 (COVID-19): protecting hospitals from the invisible. *Ann Intern Med*. (2020) 172:619–20. doi: 10.7326/M20-0751
18. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system REsilience PROGRAM (REPROGRAM) International Consortium (Part 2). *Front Public Health*. (2020) 8:410. doi: 10.3389/fpubh.2020.00410
19. Kalckreuth S, Trefflich F, Rummel-Kluge C. Mental health related internet use among psychiatric patients: a cross-sectional analysis. *BMC Psychiatry*. (2014) 14:368. doi: 10.1186/s12888-014-0368-7
20. Salisbury C, O'Cathain A, Edwards L, Thomas C, Gaunt D, Hollinghurst S, et al. Effectiveness of an integrated telehealth service for patients with depression: a pragmatic randomised controlled trial of a complex intervention. *Lancet Psychiatry*. (2016) 3:515–25. doi: 10.1016/S2215-0366(16)00083-3
21. Peek HS, Richards M, Muir O, Chan SR, Caton M, MacMillan C. Blogging and social media for mental health education and advocacy: a review for psychiatrists. *Curr Psychiatry Rep*. (2015) 17:88. doi: 10.1007/s11920-015-0629-2

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OPINION
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Telemedicine for Tobacco Cessation and Prevention to Combat COVID-19 Morbidity and Mortality in Rural Areas

Ashley L. Merianos[1]*, *Bradley Fevrier*[2] and *E. Melinda Mahabee-Gittens*[3,4]

[1] School of Human Services, University of Cincinnati, Cincinnati, OH, United States, [2] Department of Public and Allied Health, Bowling Green State University, Bowling Green, OH, United States, [3] Division of Emergency Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, United States, [4] College of Medicine, University of Cincinnati, Cincinnati, OH, United States

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***Correspondence:**
Ashley L. Merianos
ashley.merianos@uc.edu

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) outbreak has reached pandemic proportions with a large global footprint (1). In December 2019, COVID-19 was first reported in Wuhan, Hubei Province, China (1). On 28 January 2020, the National Health Commission of People's Republic of China released national strategies for assisting prevention efforts for rural areas and the older adult population (2). Nevertheless, this outbreak was not contained, and as of 16 December 2020, it has spread to 191 countries resulting in over 74 million cases and 1,646,687 deaths worldwide (3).

To date, over 16.9 million cases and 307,064 deaths have been reported in the United States (U.S.), with numbers climbing disproportionately on a day-to-day basis (3). New epidemiologic and clinical evidence is constantly evolving related to this infection while the pandemic is hastily progressing worldwide. Rapid efforts are needed to protect vulnerable populations including those living in rural areas. For example, before this pandemic, U.S. urban hospitals were over twice as likely to have growth in number of intensive care unit (ICU) beds available over a 1-year period compared to rural hospitals (4). Thus, rural hospitals are not as likely to have the higher level of resources and medical care needed for this crisis. Preventive and resource allocation strategies [e.g., ventilator availability (5)] are needed to reach and care for vulnerable rural populations.

To help address this public health challenge, telemedicine efforts have greatly expanded to provide a "safety-net" of medical and preventive care for vulnerable populations worldwide (6, 7). Although offering telemedicine services in rural areas is encouraged to reduce in-person infection risks, geographical disparities exist in the access and availability of telemedicine. This is in part due to unreliable internet in some U.S. and international rural areas (7, 8). Economic-related concerns for offering virtual services in rural areas include weakened healthcare system infrastructures, physician shortages, and a disproportionate number of residents having low-income, no health insurance, or inadequate insurance coverage for telemedicine visits (9).

TABLE 1 | Prevalence of current tobacco product use overall, and by rural-urban geographical location among U.S. Adults >18 years old.

Current product use type[a]	Overall	Rural	Urban
Any tobacco product	25.4%	35.0%	31.0%
Cigarettes	20.6%	28.5%	25.1%
Cigars	4.8%	2.6%	4.6%
Smokeless Tobacco	3.4%	8.6%	6.0%
E-Cigarettes[b]	-	2.8%	2.1%

e-cigarettes, electronic cigarettes.
[a]Data from SAMHSA, 2017 (16).
[b]Data from Mumford et al., 2019 (17). Overall e-cigarette prevalence statistic was not provided.

There is a call to action to address COVID-19 disparities that are disproportionately affecting vulnerable communities, including those: living in remote areas, with chronic diseases and risk factors such as tobacco use, and from low socioeconomic backgrounds (10). An early systematic literature review (11) hypothesized that smoking behavior may be associated with adverse progression of COVID-19, and a subsequent meta-analysis discovered that smokers were nearly two times more likely to have severity progression than non-smokers (12). However, there are limited data available on the clinical characteristics of COVID-19 infected individuals living in rural areas. The purpose of this commentary is to review information on existing U.S. tobacco use disparities in rural areas and knowledge available on tobacco use and COVID-19 outcomes. We also provide suggestions on future directions for tobacco cessation efforts reaching rural smokers during this pandemic.

TOBACCO USE AND COVID-19

Tobacco Use and COVID-19 Disparities Among U.S. Rural Adults

Tobacco users living in U.S. rural areas may represent an additional subgroup at risk for higher COVID-19-related morbidity. Irrespective of COVID-19, individuals living in rural areas have high rates of tobacco use and related morbidity compared to urban or metropolitan area dwellers due to several factors including: low income, low educational attainment, higher social acceptability to tobacco use, permissive tobacco control policies, and lack of healthcare access (13, 14). Rural communities are heterogenous in nature, but low socioeconomic indicators largely contribute to the rural-urban disparity gap of poor health behaviors such as smoking and COVID-19 mortality rates (15).

Table 1 shows that U.S. rural residents generally have higher tobacco use rates and lower smoking cessation rates than urban residents (16–19). Rural adult residents also have a high prevalence of smoking-related, long-term health consequences and causes of mortality (20). Over one-quarter (26%) of rural adult residents have one chronic health condition (e.g., diabetes) and about 36% have two or more conditions (21). The top leading causes of death among rural dwellers include cancer, heart disease, chronic lower respiratory disease, and stroke (22). The Centers for Disease Control and Prevention indicates that those deemed high risk for severe COVID-19 are older adults, individuals with medical conditions including those with lung disease, heart conditions, and diabetes, and individuals living in rural communities (23). A meta-analysis (24) suggests smoking and chronic health conditions are the most common underlying factors reported among patients hospitalized for COVID-19. Given that rural residents have high rates of combustible and non-combustible tobacco/nicotine product use and related chronic health conditions that place them at risk for poor health outcomes and excess mortality, it is important to synthesize the evidence available on adverse COVID-19 specific outcomes in this population.

Tobacco Use and COVID-19-Related Morbidity and Mortality

The initial epidemiological and clinical data available retrospectively assessed adult patients who sought treatment in Wuhan where COVID-19 first emerged (25–28). It is important to note that approximately 45% of individuals in China reside in rural areas and face similar issues to the U.S. rural population, such as lack of healthcare access and affordability (29, 30). These studies report that patients who presented with COVID-19 had symptoms similar to commonly reported symptoms of tobacco use (e.g., cough, respiratory-related symptoms) as outlined by the U.S. Surgeon General (20). Patients presenting with COVID-19 also had high rates of comorbidities (25–27, 31) that have been causally linked to tobacco use including hypertension, cardiovascular disease, and diabetes (20).

Recent literature reviews found that tobacco use is associated with poor disease progression (32), and that severe COVID-19 outcomes among tobacco users are further perpetuated among those with these pre-existing conditions (33). One study found patients with a smoking history were over 14 times more likely to experience disease progression than patients with no smoking history after adjustment for important factors including patient age (27). Additional research reports that over one-fourth (26%) of current smokers and about 8% of former smokers were admitted to the ICU, needed mechanical ventilation, or died (17). Concerning COVID-19 mortality-related risk factors, of 11 admitted patients who were current smokers in China, five did not survive (28). A more recent U.S. study found that current smokers, when compared to never smokers, were at increased risk of needing mechanical ventilation, having severe-to-critical illness, lower survival time in days, and more deaths (34). Concerning non-combustible tobacco products, a study found that 13–24-year-olds who engaged in exclusive e-cigarette use and dual-use of e-cigarettes and combustible cigarettes were at significantly increased odds to have positive COVID-19 diagnoses, while accounting for clustering by U.S. states and regions (35). Despite limitations of the rapidly emerging available data, such as relying on electronic medical record data for smoking status, it is likely that combustible and non-combustible

tobacco product use influences COVID-19 progression and negative health outcomes including death. Thus, a recent review concluded that smoking cessation is expected to reduce COVID-19-related risks and severe complications, and acknowledged telemedicine as one tool that can be employed to promote quitting smoking (36).

Telemedicine for the Treatment of Tobacco Use and Dependence During and Beyond COVID-19

A recent epidemiologic model that has informed related policy suggests that public health measures including physical distancing would be needed for 3 months to decrease the COVID-19 peak impact on the healthcare system (37). The model suggests these measures should be maintained intermittently over 12–18 months while the disease remains detected in individuals and until a vaccine is made widely available (37). Social distancing mandates naturally reinforce the need to rapidly implement or augment communication modalities that can be used with individuals and groups who may not be able to meet face-to-face and live in multiple locations (38). Fortunately, there are many tobacco cessation programs that have already expanded their reach to rural tobacco users with high prevalence rates (39) who may have limited access to in-person programs, irrespective of COVID-19 restrictions. These programs have demonstrated acceptability and efficacy and include smokefree.gov and other internet-based programs (40, 41), telephone programs (e.g., tobacco Quitline) (42) and mobile phone-based programs (e.g., texting) (43). Therefore, it is important to expand the reach of telemedicine to address the rural-urban geographic inequities and improve the access, delivery, and efficiency of preventive health services among rural areas globally (7).

Promoting Evidence-Based Treatment for Tobacco Use and Dependence Delivered via Telemedicine to Rural Areas During and Beyond COVID-19

In light of the concerns that tobacco use increases the risk of COVID-19-related morbidity and mortality, measures are needed to mitigate illness progression in infected individuals. Given concerns about contracting COVID-19 and evidence of possible increased risk for smokers and vapers, this pandemic may have a positive impact on decreasing smoking and vaping rates. During this pandemic, telemedicine modalities can continue to provide, expand, and improve the delivery of evidence-based information, which includes the "5 A's of tobacco cessation (44)." The first step is to Ask about tobacco use—this would be complete if the smoker has enrolled into a program. The second step is to Advise to quit—during this step, telemedicine-based programs should capitalize on this "teachable moment" (45) by incorporating messaging that leverages concerns about COVID-19 and the benefits of quitting smoking and/or vaping as a way to reinforce the "Advise" portion. There are increases in smoking abstinence rates when cessation interventions are conducted during "teachable moments" such as during children's visits for acute illnesses (46), during cancer screenings (47), when having a cancer diagnosis (48), when initiating HIV treatment (49), and during pregnancy (50). The third step is to Assess readiness to quit—this can be easily assessed by phone-, video-, or web-based programs. The fourth step is to Assist in quitting—this includes the recommendation to offer pharmacotherapy such as nicotine replacement therapy, which has shown efficacy in increasing cessation rates (51). The fifth step is to Arrange follow-up—during this time of social isolation, tobacco users need help and support. The knowledge that there are many options such as online chat groups or telephone counselors that are available will provide them with much needed support and encouragement.

Incorporating telemedicine during this critical period may increase its use among remote and hard-to-reach rural populations over time. One U.S. cancer center successfully used telemedicine to deliver individual and group tobacco treatment virtually to tobacco-dependent cancer patients (52). They reported improved attendance and engagement at telehealth visits compared to prior in-person visits. Another study conducted among current smokers <25 years old who participated in the Youth Quitline services in Hong Kong found that over 4-in-10 agreed the pandemic was a motivator to quit tobacco use, over 7-in-10 changed their tobacco use habits due to public health measures (e.g., wearing a mask), and nearly 6-in-10 reduced their daily cigarette consumption (53). Therefore, telemedicine has the potential to decrease patient-level barriers to in-person tobacco cessation treatment among all ages worldwide, such as lack of transportation, childcare, and travel costs. Moreover, the opportunity to offer continuous cessation encouragement and support may also increase quit rates during and beyond COVID-19 restrictions.

DISCUSSION

Public health campaigns that reach vulnerable rural populations are highly warranted to promote the availability of remote tobacco cessation and prevention initiatives during this pandemic. Rural populations have higher rates of poverty, chronic illnesses, poor healthcare access, and lack of insurance—all of which are risk factors for COVID-19 (8, 9). Thus, they could greatly benefit from low-cost telemedicine programs that are easily accessible to decrease tobacco-related morbidity. Some countries have implemented tobacco product sales bans and other policy measures during the pandemic to help mitigate possible viral transmission (e.g., sharing tobacco products), which provides an exceptional opportunity to decrease the global tobacco use burden (54). In addition to telemedicine services, these measures include leveraging new technology to encourage and support tobacco users to quit smoking with evidence-based resources. For example, the tobacco Quitline number could be promoted among rural smokers and vapers. Healthcare professionals and tobacco treatment specialists who interact with rural residents, for example, should be involved in offering evidence-based tobacco cessation interventions via telemedicine. Large-scale public health interventions delivered

via telemedicine should be targeted to tobacco users who live in rural areas.

AUTHOR CONTRIBUTIONS

AM conceptualized the article, drafted the manuscript, and approved the final manuscript as submitted. BF conceptualized the article, drafted the manuscript, and approved the final manuscript as submitted. EM-G conceptualized the article, drafted the manuscript, and approved the final manuscript as submitted. All authors contributed to the article and approved the submitted version.

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REFERENCES

1. Zhu N, Zhang D, Wang D, Wang W, Li X, Yang B, et al. A novel coronavirus from patients with pneumonia in China, 2019. *N. Engl. J. Med.* (2020) 382:727–33. doi: 10.1056/NEJMoa2001017
2. Adhikari SP, Meng S, Wu Y, Mao Y, Ye R, Wang Q, et al. Epidemiology, causes, clinical manifestation and diagnosis, prevention and control of coronavirus disease (COVID-19) during the early outbreak period: a scoping review. *Infect Dis. Poverty*. (2020) 9:29. doi: 10.1186/s40249-020-00646-x
3. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect. Dis.* (2020) 20:533–4. doi: 10.1016/S1473-3099(20)30120-1
4. Wallace DJ, Seymour CW, Kahn JM. Hospital-level changes in adult ICU bed supply in the United States. *Crit. Care Med.* (2017) 45:e67–76. doi: 10.1097/CCM.0000000000002051
5. Koonin LM, Pillai S, Kahn EB, Moulia D, Patel A. Strategies to inform allocation of stockpiled ventilators to healthcare facilities during a pandemic. *Health Secur*. (2020) 18:69–74. doi: 10.1089/hs.2020.0028
6. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine across the globe-position paper from the COVID-19 Pandemic Health System Resilience PROGRAM (REPROGRAM) International Consortium (Part 1). *Front. Public Health*. (2020) 8:556720. doi: 10.3389/fpubh.2020.556720
7. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system Resilience PROGRAM (REPROGRAM) International Consortium (Part 2). *Front. Public Health*. (2020) 8:410. doi: 10.3389/fpubh.2020.00410
8. Centers for Disease Control and Prevention. *COVID-19 (coronavirus disease): Rural Communities*. (2020). Available online at: https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/other-at-risk-populations/rural-communities.html (accessed December 15, 2020).
9. Melvin SC, Wiggins C, Burse N, Thompson E, Monger M. The role of public health in COVID-19 emergency response efforts from a rural health perspective. *Prev. Chronic Dis*. (2020) 17:E70. doi: 10.5888/pcd17.200256
10. Bhaskar S, Rastogi A, Menon KV, Kunheri B, Balakrishnan S, Howick J. Call for action to address equity and justice divide during COVID-19. *Front. Psychiatry*. (2020) 11:559905. doi: 10.3389/fpsyt.2020.559905
11. Vardavas C, Nikitara K. COVID-19 and smoking: a systematic review of the evidence. *Tob. Induc. Dis*. (2020) 18:20. doi: 10.18332/tid/119324
12. Patanavanich R, Glantz SA. Smoking is associated with COVID-19 progression: a meta-analysis. *Nicotine Tob. Res*. (2020) 22:1653–6. doi: 10.1093/ntr/ntaa082
13. American Lung Association. *Cutting Tobacco's Rural Roots: Tobacco Use in Rural Areas* (2015). Available online at: https://healthforward.org/wp-content/uploads/2015/07/cutting-tobaccos-rural-roots.pdf (accessed August 25, 2020).
14. Talbot JA, Williamson ME, Pearson K, Lenardson J, Ziller E, Jimenez F, et al. Advancing tobacco prevention and control in rural America. Washington, DC: National Network of Public Health Institute (2019).
15. Parcha V, Malla G, Suri SS, Kalra R, Heindl B, Berra L, et al. Geographic variation in racial disparities in health and coronavirus disease-2019 (COVID-19) mortality. *Mayo Clin. Proc. Innov. Qual. Outcomes*. (2020) 4:703–16. doi: 10.1016/j.mayocpiqo.2020.09.005
16. Substance Abuse and Mental Health Services Administration, (SAMHSA). *Results From the 2016 National Survey on Drug Use and Health: Detailed Tables*. (2017). Available online at: https://www.samhsa.gov/data/sites/default/files/NSDUH-DetTabs-2016/NSDUH-DetTabs-2016.pdf (accessed August 25, 2020).
17. Mumford EA, Stillman FA, Tanenbaum E, Doogan NJ, Roberts ME, Wewers ME, et al. Regional rural-urban differences in e-cigarette use and reasons for use in the United States. *J. Rural Health*. (2019) 35:395–404. doi: 10.1111/jrh.12333
18. Roberts ME, Doogan NJ, Kurti AN, Redner R, Gaalema DE, Stanton CA, et al. Rural tobacco use across the United States: how rural and urban areas differ, broken down by census regions and divisions. *Health Place*. (2016) 39:153–9. doi: 10.1016/j.healthplace.2016.04.001
19. Ziller EC, Lenardson JD, Paluso NC, Talbot JA, Daley A. Rural-urban differences in the decline of adolescent cigarette smoking. *Am. J. Public Health*. (2019) 109:771–3. doi: 10.2105/AJPH.2019.304995
20. U.S. Department of Health and Human Services. *The Health Consequences of Smoking - 50 Years of Progress: A Report of the Surgeon General*. Rockville, MD: U.S. Department of Health and Human Services, Office of the Surgeon General (2014).
21. James CV, Moonesinghe R, Wilson-Frederick SM, Hall JE, Penman-Aguilar A, Bouye K. Racial/ethnic health disparities among rural adults - United States, 2012-2015. *MMWR Surveill. Summ*. (2017) 66:1–9. doi: 10.15585/mmwr.ss6623a1
22. Garcia MC, Rossen LM, Bastian B, Faul M, Dowling NF, Thomas CC, et al. Potentially excess deaths from the five leading causes of death in metropolitan and nonmetropolitan counties - United States, 2010-2017. *MMWR Surveill. Summ*. (2019) 68:1–11. doi: 10.15585/mmwr.ss6810a1
23. Centers for Disease Control and Prevention. *COVID-19 (coronavirus Disease): People at Increased Risk*. (2020). Available online at: https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/index.html (accessed December 15, 2020).
24. Emami A, Javanmardi F, Pirbonyeh N, Akbari A. Prevalence of underlying diseases in hospitalized patients with COVID-19: a systematic review and meta-analysis. *Arch. Acad. Emerg. Med*. (2020) 8:e35. doi: 10.1371/journal.pone.0241265
25. Zhang J, Dong X, Cao Y, Yuan Y, Yang Y, Yan Y, et al. Clinical characteristics of 140 patients infected with SARS-CoV-2 in Wuhan, China. *Allergy*. (2020) 75:1730–41. doi: 10.1111/all.14238
26. Guan W, Ni Z, Hu Y, Liang W, Ou C, He J, et al. Clinical characteristics of coronavirus disease 2019 in China. *N. Engl. J. Med*. (2020) 382:1708–20. doi: 10.1056/NEJMoa2002032
27. Liu W, Tao Z, Lei W, Ming-Li Y, Kui L, Ling Z, et al. Analysis of factors associated with disease outcomes in hospitalized patients with 2019 novel coronavirus disease. *Chin. Med. J.* (2020) 133:1032–8. doi: 10.1097/CM9.0000000000000775
28. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in

Wuhan, China: a retrospective cohort study. *Lancet.* (2020) 395:1054–62. doi: 10.1016/S0140-6736(20)30566-3
29. Cheng J, Yuan Y, Lu W, Yang L. Primary health care in China: is China's health reform for the whole nation? *Prim. Health Care Res. Dev.* (2017) 18:398–403. doi: 10.1017/S1463423617000111
30. Liu Y, Rao K, Wu J, Gakidou E. Health system reform in China 7: China's health system performance. *Lancet.* (2008) 372:1914–23. doi: 10.1016/S0140-6736(08)61362-8
31. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet.* (2020) 395:497–506. doi: 10.1016/S0140-6736(20)30183-5
32. Shastri MD, Shukla SD, Chong WC, KC R, Dua K, Patel RP, et al. Smoking and COVID-19: what we know so far. *Respir. Med.* (2020) 176:106237. doi: 10.1016/j.rmed.2020.106237
33. Gupta AK, Nethan ST, Mehrotra R. Tobacco use as a well-recognized cause of severe COVID-19 manifestations. *Respir. Med.* (2020) 176:106233. doi: 10.1016/j.rmed.2020.106233
34. Adrish M, Chilimuri S, Mantri N, Sun H, Zahid M, Gongati S, et al. Association of smoking status with outcomes in hospitalised patients with COVID-19. *BMJ Open Respir. Res.* (2020) 7:e000716. doi: 10.1136/bmjresp-2020-000716
35. Gaiha SM, Cheng J, Halpern-Felsher B. Association between youth smoking, electronic cigarette use, and coronavirus disease 2019. *J. Adolesc. Health.* (2020) 67:519–23. doi: 10.1016/j.jadohealth.2020.07.002
36. Kashyap VK, Dhasmana A, Massey A, Kotnala S, Zafar N, Jaggi M, et al. Smoking and COVID-19: adding fuel to the flame. *Int. J. Mol. Sci.* (2020) 21:6581. doi: 10.3390/ijms21186581
37. Ferguson NM, Laydon D, Nedjati-Gilani G, et al. *Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand.* Imperial College COVID-19 Response Team (2020). Available online at: https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf (accessed August 25, 2020).
38. Hollander JE, Carr BG. Virtually perfect? Telemedicine for Covid-19. *N. Engl. J. Med.* (2020) 382:1679–81. doi: 10.1056/NEJMp2003539
39. Cepeda-Benito A, Doogan NJ, Redner R, Roberts ME, Kurti AN, Villanti AC, et al. Trend differences in men and women in rural and urban U.S. settings. *Prev. Med.* (2018) 117:69–75. doi: 10.1016/j.ypmed.2018.04.008
40. Bricker JB, Mull KE, McClure JB, Watson NL, Heffner JL. Improving quit rates of web-delivered interventions for smoking cessation: full-scale randomized trial of WebQuit.org vs. Smokefree.gov. *Addiction.* (2018) 113:914–23. doi: 10.1111/add.14127
41. Taylor GMJ, Dalili MN, Semwal M, Civljak M, Sheikh A, Car J. Internet-based interventions for smoking cessation. *Cochrane Database Syst. Rev.* (2017) 9:CD007078. doi: 10.1002/14651858.CD007078.pub5
42. Matkin W, Ordonez-Mena JM, Hartmann-Boyce J. Telephone counselling for smoking cessation. *Cochrane Database Syst. Rev.* (2019) 5:CD002850. doi: 10.1002/14651858.CD002850.pub4
43. Whittaker R, McRobbie H, Bullen C, Rodgers A, Gu Y, Dobson R. Mobile phone text messaging and app-based interventions for smoking cessation. *Cochrane Database Syst. Rev.* (2019) 10:CD006611. doi: 10.1002/14651858.CD006611.pub5
44. The Clinical Practice Guideline Treating Tobacco Use and Dependence 2008 Update Panel, Liaisons, and Staff. A Clinical Practice Guideline for Treating Tobacco Use and Dependence: 2008 update. A U.S. public health service report. *Am. J. Prev. Med.* (2008) 35:158–76. doi: 10.1016/j.amepre.2008.04.009
45. McBride CM, Emmons KM, Lipkus IM. Understanding the potential of teachable moments: the case of smoking cessation. *Health Educ. Res.* (2003) 18:156–70. doi: 10.1093/her/18.2.156
46. Behbod B, Sharma M, Baxi R, Roseby R, Webster P. Family and carer smoking control programmes for reducing children's exposure to environmental tobacco smoke. *Cochrane Database Syst. Rev.* (2018) 1:CD001746. doi: 10.1002/14651858.CD001746.pub4
47. Piñeiro B, Simmons VN, Palmer AM, Correa JB, Brandon TH. Smoking cessation interventions within the context of low-dose computed tomography lung cancer screening: a systematic review. *Lung Cancer.* (2016) 98:91–8. doi: 10.1016/j.lungcan.2016.05.028
48. Westmaas JL, Newton CC, Stevens VL, Flanders WD, Gapstur SM, Jacobs EJ. Does a recent cancer diagnosis predict smoking cessation? An analysis from a large prospective US cohort. *J. Clin. Oncol.* (2015) 33:1647–52. doi: 10.1200/JCO.2014.58.3088
49. Vidrine DJ, Frank SG, Savin MJ, Waters AJ, Li Y, Chen S, et al. HIV care initiation: a teachable moment for smoking cessation? *Nicotine Tob. Res.* (2018) 20:1109–16. doi: 10.1093/ntr/ntx218
50. Chamberlain C, O'Mara-Eves A, Porter J, Coleman T, Perlen SM, Thomas J, et al. Psychosocial interventions for supporting women to stop smoking in pregnancy. *Cochrane Database Syst. Rev.* (2017) 2:CD001055. doi: 10.1002/14651858.CD001055.pub5
51. Lindson N, Chepkin SC, Ye W, Fanshawe TR, Bullen C, Hartmann-Boyce J. Different doses, durations and modes of delivery of nicotine replacement therapy for smoking cessation. *Cochrane Database Syst. Rev.* (2019) 4:CD013308. doi: 10.1002/14651858.CD013308
52. Kotsen C, Dilip D, Carter-Harris L, O'Brien M, Whitlock CW, de Leon-Sanchez S, et al. Rapid scaling up of telehealth treatment for tobacco-dependent cancer patients during the COVID-19 outbreak in New York City. *Telemed. J. E Health.* (2020). doi: 10.1089/tmj.2020.0194. [Epub ahead of print].
53. Ho LLK, Li WHC, Cheung AT, Xia W, Wang MP, Cheung DYT, et al. Impact of COVID-19 on the Hong Kong Youth Quitline Service and quitting behaviors of its users. *Int. J. Environ. Res. Public Health.* (2020) 17:8397. doi: 10.3390/ijerph17228397
54. Ahluwalia IB, Myers M, Cohen JE. COVID-19 pandemic: an opportunity for tobacco use cessation. *Lancet Public Health.* (2020) 5:e577. doi: 10.1016/S2468-2667(20)30236-X

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COVID-19 and Teleneurology in Sub-Saharan Africa: Leveraging the Current Exigency

Philip Babatunde Adebayo[1]*, *Olusegun John Oluwole*[2] and *Funmilola Tolulope Taiwo*[3]

[1] Neurology Section, Department of Internal Medicine, Aga Khan University, Dar es Salaam, Tanzania, [2] Department of Neurology, King's College Hospital, Dubai, United Arab Emirates, [3] Department of Neurology, University College Hospital, Ibadan, Nigeria

Africa has over 1.3 billion inhabitants, with over 60% of this population residing in rural areas that have poor access to medical experts. Despite having a ridiculously huge, underserved population, very few African countries currently have any form of sustained and organized telemedicine practice, and even fewer have dedicated tele-neurology services. The ongoing COVID-19 pandemic has proved to be one of the most significant disruptors of vital sectors of human endeavor in modern times. In the healthcare sector, there is an increasing advocacy to deliver non-urgent care *via* telemedicine. This paper examined the current state of tele-neurology practice and infrastructural preparedness in sub-Saharan Africa. Currently, there is over 70% mobile phone penetration in most of the countries and virtually all of them have mobile internet services of different technologies and generations. Although the needed infrastructure is increasingly available, it should be improved upon. We have proposed the access, costs, ethics, and support (ACES) model as a bespoke, holistic strategy for the successful implementation and advancement of tele-neurology in sub-Saharan Africa.

Keywords: COVID-19, telehealth, teleneurology, coronavirus, Africa

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***Correspondence:**
Philip Babatunde Adebayo
philipab8@yahoo.com

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INTRODUCTION

Coronavirus disease-2019 (COVID-19), caused by severe acute respiratory syndrome-coronavirus-2 (SARS-COV-2), broke out in the Hubei province of China in December 2019 and later became a pandemic that has now afflicted over 200 countries of the world (1). So far, COVID-19 has caused over seven million infections and over 400,000 deaths worldwide, with the highest burdens being in the United States of America (USA), selected Western European countries, and China (2). As the epidemic intensified, healthcare systems in many parts of the world rapidly became overwhelmed with severe and complicated cases of the disease for which hospitalizations and critical care are needed. Consequently, the re-deployment of healthcare workers and the repurposing of healthcare resources and facilities became a necessity in many countries to combat the existential threat posed by the virus (3, 4).

Neurology services came under severe pressure during COVID-19 due to the limited availability of neurology specialist providers and reconfiguration of existing healthcare services (4–6). Although the chronic neurology outpatient clinics were disrupted, acute services continued under the aegis of ED or neurosurgery, in those requiring critical attention (7). The situation became compounded by the widespread enforcement of lockdown measures, making it difficult for non-COVID-19 patients to access health services in places where they were still available. Furthermore,

the extreme vulnerability to COVID-19 of the elderly population and those with underlying chronic medical conditions, which typify a large proportion of our neurology patients, created additional disincentives and barriers to seeking healthcare by this category of patients even when there were obvious and urgent indications for such. For example, stroke centers in Europe reported receiving much fewer acute stroke cases during this period than previously (8).

Although the full impact of the COVID-19 pandemic is yet to be evaluated in the sub-Saharan Africa (SSA) context, empirical evidence suggests a severe restriction of conventional service provision and face-to-face consultations. Few centers around the continent continue to provide neurology services via tele-neurology. Some centers with no existing tele-neurology scheme have had to develop an *ad-hoc* system that served their patient population (9). Given the low median neurologist to population ratio in Africa (0.03;100,000) compared to Europe (4.84: 100,000) (10), it is posited that tele-neurology will continue to assume increasing expansion and uptake in SSA post- COVID-19 era (11, 12). However, an estimate of the population that may benefit from tele-neurology expansion and lack of evidence for its cost-effectiveness are current gaps. Although a part of the world's second-largest continent, SSA is the region with the lowest level of economic, technological, and internet development globally, in addition to its colossal healthcare burden (13–15). In this paper, we have briefly highlighted the low-hanging fruits, and categorized them into access, costs, ethics and support (ACES) issues, which, if addressed, will improve tele-neurology practice to become a well-organized and attractive practice and service option in SSA.

CURRENT STATE OF TELEHEALTH AND TELE-NEUROLOGY IN SUB-SAHARAN AFRICA

The delivery of health care, health education, and health information services via remote technologies is referred to as telehealth (16). Telemedicine, often used interchangeably with telehealth, refers explicitly to the remote diagnosis and treatment of patients utilizing telecommunications technology such as telephone or exchange of information through video or images (16). Teleneurology may be defined as remote provision of neurological care, conferencing and education using various technologies to achieve connectivity, including telephone and the internet (17, 18).

Africa currently has over 1.3 billion population, with about 60% of this population residing in rural areas (19, 20). This is particularly true of sub-Saharan Africa. Despite having more people living in rural areas, medical specialists, including neurologists, are concentrated in the urban areas making access to specialist medical care difficult for most. The existing condition of healthcare service delivery in SSA is viewed as a kind of ongoing crisis-management, complete with rationing and triaging (21). This prevalent situation is occasioned by inadequate funding, inadequate personnel, inadequate training, and underserviced equipment. It is an uphill task in the light of the foregoing, to provide the desired level of quality care that SSA deserve in rural and urban settings (21).

There have been pockets of Telehealth services and Teleneurology initiatives across SSA before the pandemic. Telemedicine has been effectively utilized in other disciplines such as Opthalmology (22), HIV medicine (23), clinical psychology and psychiatry (24, 25), radiology (26), dermatology (27), neurosurgery (28), and maternal and child health (29). Although reports of organized teleneurology are limited, few teleneurology initiatives are beginning to emerge from the subcontinent. The Disease Relief through Excellent and Advanced Means (DREAM) program has incorporated a teleneurology service into its operation (30). DREAM has been operating in 11 SSA countries since 2002. The initiative provides free-to-all health services for the prevention and treatment of HIV/AIDS. The DREAM teleneurology effort proves that an established telemedicine system can launch other telehealth initiatives. In 2016, the first Arab-African teleneurology conference was held, and a "treat and teach" teleneurology initiative was recommended. The initiative aims to nurture local neurology leaders by using new telecommunication technologies to improve their knowledge and management skills while ensuring sustainability by integrating teleneurology into daily clinical practice within an existing health system using the hub and spoke model (31). One of this initiative's successes is the regular hosting of the African Movement Disorders Grand Round, a multicentre webinar series to which many African neurologists may freely connect for educational purposes (32). Most available telehealth programs deploy mobile health services to increase access to healthcare and health education (33). This model has enhanced monitoring of blood pressure control in stroke survivors (34, 35), epilepsy diagnosis, care and follow up (36), movement disorders education (37), and the care of patients with Parkinson's disease (38). Its potential role in telerehabilitation has also been evaluated (39). During the pandemic, mobile health has sustained teleconsultations (40) and remote care for epilepsy (41).

Although no randomized controlled trials have evaluated the efficacy and cost effectiveness of teleneurology in SSA, Sarfo et al. (42) had proposed the establishment of trans-continental, inter-regional, intra-regional, and national networks of neurologists to utilize teleneurology platforms to improve the reach of neurology care in SSA (42). The feasibility and acceptability of such modalities require extensive research given the different political situations, different subcontinental and national laws, healthcare as well as data sharing policies across countries in SSA. The above been said, SSA is no less prepared to utilize the advantages that teleneurology offers.

AFRICA'S TELECOMMUNICATION INFRASTRUCTURE

Available information reveals mobile internet as the major source of internet connectivity in most of Africa, with many countries having high mobile phone penetration, reaching up to 90% (**Figure 1**). By early 2019, countries such as South Africa,

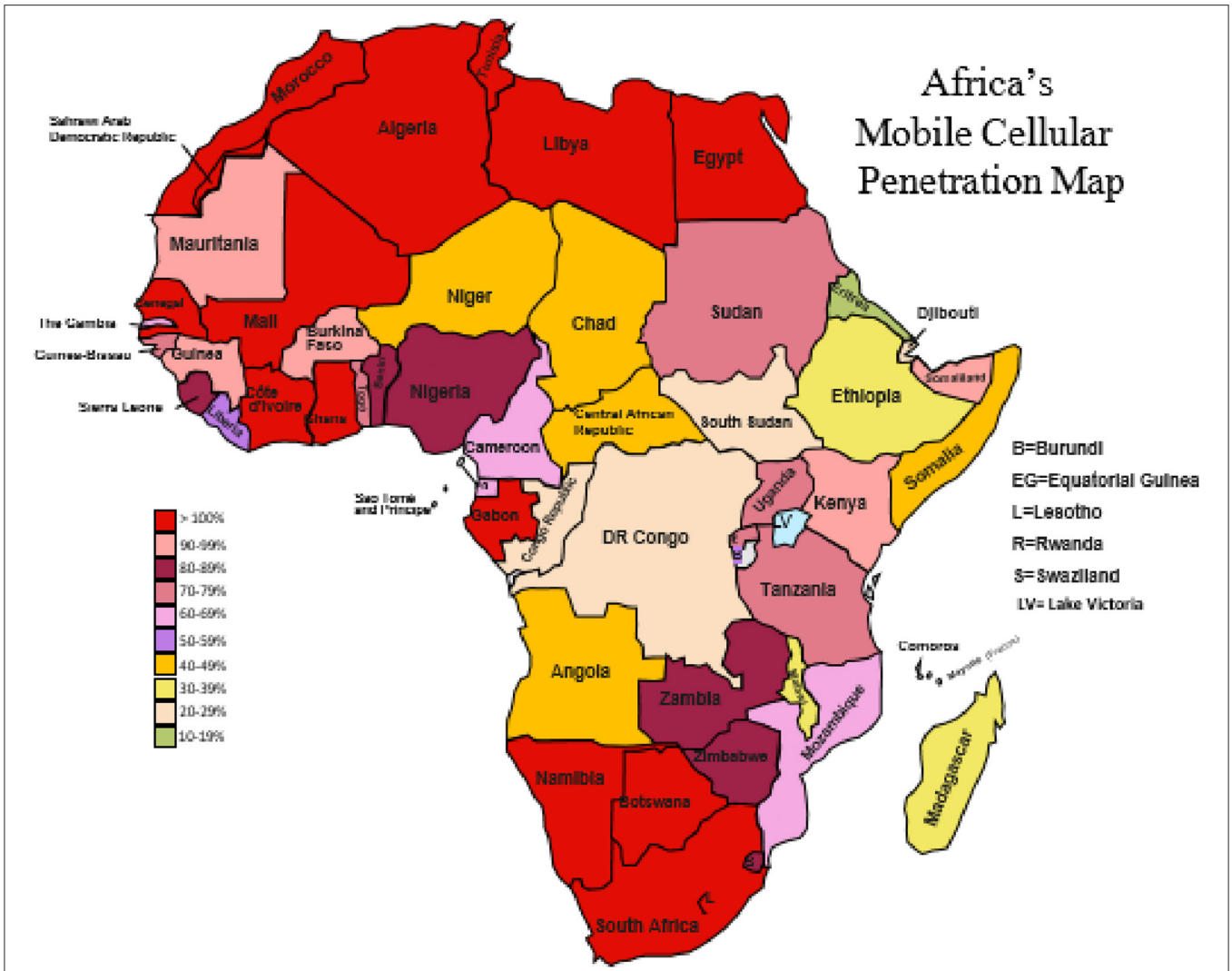

FIGURE 1 | Africa's mobile cellular penetration map.

Botswana, Gabon, Kenya and Mauritius had well over 100% mobile phone penetration (mainly attributed to the fact that most users own more than one SIM card either from the same or different service providers) (43), though there were few countries which still had <50% penetration at that time, mostly due to political upheavals and wars (44). Such countries included Madagascar, Malawi, and Sudan (16). Mobile internet services are dispensed or sold to citizens in monthly/weekly data plans that are separate from calling plans. The mobile internet connections are often not available in rural communities. Also, not all of the cities where the connections exist have access to broadband internet. In many of such cities in SSA, the governments and internet service providing companies are still in the process of either upgrading outmoded existing infrastructures to provide broadband capabilities or expanding them to provide some form of basic low bandwidth internet connectivity in places where they have not yet existed.

Nigeria currently has broadband coverage of about 30% and plans to increase it to 70% by 2021. Ghana also recently began to implement an upgrade from 2G low bandwidth to 3G (44). In the cities where mobile broadband has become available, high pricing and congestion remain as obstacles. The situation appears different in northern Africa, with Egypt having a decent coverage of fixed-line broadband internet connectivity in homes and offices in addition to ubiquitous mobile internet available for personal use (44). Similarly, Tunisia is reputed as having one of the most sophisticated telecommunications and broadband infrastructures in North Africa. Outside of northern Africa, there is evidence that South Africa is making increasing strides in the area of fixed-line broadband (44).

Although broadband internet is still not universally available in all countries in Africa, the fair availability of modest internet technology coupled with decent mobile penetration provides the opportunity to improve telehealth and indeed, tele-neurology

practice. Certainly, some types of teleneurology practices such as remote patient monitoring (RPM) might be impracticable in rural communities where the internet connectivity and the available technologies are too basic or weak to support the required mobile applications.

The model of transcontinental and transnational tele-neurology approach proposed by Sarfo et al. (42), has already been practiced by other disciplines. For example, Wamala et al. reveals the existence of some form of organized telepathology services in Uganda (33), as well as organized telemedicine and tele-education programs in Bamako, Mali which had internal collaborations with Geneva, Switzerland (45). Furthermore, there is evidence of a growing structured and regulated telemedicine practice in South Africa (46). Interestingly also, there is a recently implemented pilot telemedicine initiative in maternal and child health in Nigeria covering few handpicked states in the country (47).

IMPLICATION OF COVID-19 PANDEMIC FOR TELEHEALTH AND TELENEUROLOGY IN SUB-SAHARAN AFRICA

Before this era in SSA, the bourgeoning use of telehealth has been found to have both clinical and educational significance in a way similar to high-income countries (HIC) within the disciplines that have deployed telemedicine services and in movement disorders (32, 37, 48). The COVID-19 pandemic has created undeniable and unprecedented difficulties with continuing to offer non-urgent, but certainly needed, care to a large group of our patients, including those with neurological disorders. Even after the lockdown measures are relaxed as they are beginning to, the sparse distribution of newly lauched vaccines against Sars-Cov-2 might continue to deter in-hospital care. To bridge this gap, many medical societies and associations worldwide are encouraging the adoption of telemedicine and telehealth to meet the needs of patients whose care does not necessitate direct physician contact. For example, the Association of British Neurologists (ABN) has recently published guidelines on how to establish teleneurology services during the COVID-19 pandemic effectively. In this guideline, the ABN encourages all neurology consultations to be done via telemedicine except in cases where in-person consultation is unavoidable (49).

The pandemic has undoubtedly provided an opportunity to adopt tele-neurology as a viable addition or alternative to conventional neurological practice. An obvious drawback to teleneurology is the inability to touch the patient or perform some neuro-examination aspects. The examination will need, therefore, to rely on visual inspections with the patient's assistance (49). Apart from the potential to reduce cost and improve outcomes, the real value of tele-neurology in this era lies in its ability to prevent the spread of and the exposure to potential Sars Cov-2 infection. Anecdotal report from Kenya suggests a good uptake and responsiveness to a new tele-neurology service initiated in response to the COVID-19 pandemic (9). In the same vein, the Health Professions Council of South Africa (HPCSA) had to amend the pre-existing requirements for telehealth in response to the pandemic. Now, physicians in South Africa do not need to have had prior in-person consultation with a patient before such a patient could be seen *via* telemedicine (46).

Going forward, institutions in SSA would need to progressively integrate an organized teleneurology practice into their neurology service delivery. We are proposing the ACES (Access, Cost, Ethics, and Support) framework, which attempts to put into clear perspective, the adaptable core scalable goals which institutions and telehealth stakeholders in SSA can work with. We acknowledge that political will, training, education, advocacy, and the continued level of interest in telehealth beyond COVID-19 by the different national health regulatory authorities, will play an essential role in determining whether telehealth and indeed tele-neurology will assume a different pedestal in the subcontinent.

ACES STRATEGIC FOCUS

The COVID-19 pandemic has raised pertinent questions about the delivery of health care even in urban societies. It is posited that telehealth and tele-neurology would increase with time. Currently, in SSA, tele-neurology faces a plethora of challenges such as dependency on funding, unclear healthcare system responsibilities and shortage of neurologists as well as non-physician health workers (NPHW) to provide care, leadership, and drive. In addition to the aforementioned factors, inadequate and unreliable infrastructural support for telehealth services significantly limits tele-neurology in SSA (42). Although we did not estimate the population that can potentially benefit from tele-neurology services in SSA, emerging evidence reveals that the potential for tele-neurology uptake is enormous. For example, Mcginley et al. reported a 533% increase in the usage of a tele-neurology service for all patients in an academic institution during COVID-19 era (50). The ACES model (**Figure 2**) summarizes our idea of driving new tele-neurology services beyond the COVID-19 period.

Access

To be effective and far-reaching, tele-neurology services in SSA will have to consider the demography and location of the population that it is meant to serve. Efforts to include all social classes and specific groups of people (for example, vulnerable groups) will facilitate service uptake and promote equity in access. Tele-neurology service model will have to be inter-regional and intra-regional as proposed by Sarfo et al. (42) but cannot be limited to academic institutions because there are neurologists and neurological service delivery outside of academic centers. According to the world federation of neurology (WFN) survey, only a small proportion (0–25%) of neurologists work full time in academic centers. A substantial majority (75–100%) of neurologists also work in private practice in many countries, including those in Africa (51). Using the stroke medicine model, African healthcare institutions may employ the *hub-and-spoke system*—a structure of telemedicine in which a certified comprehensive stroke center, usually in a large urban area, serves as the primary stroke center (the hub). The spokes are in remote areas, generally smaller regional rural

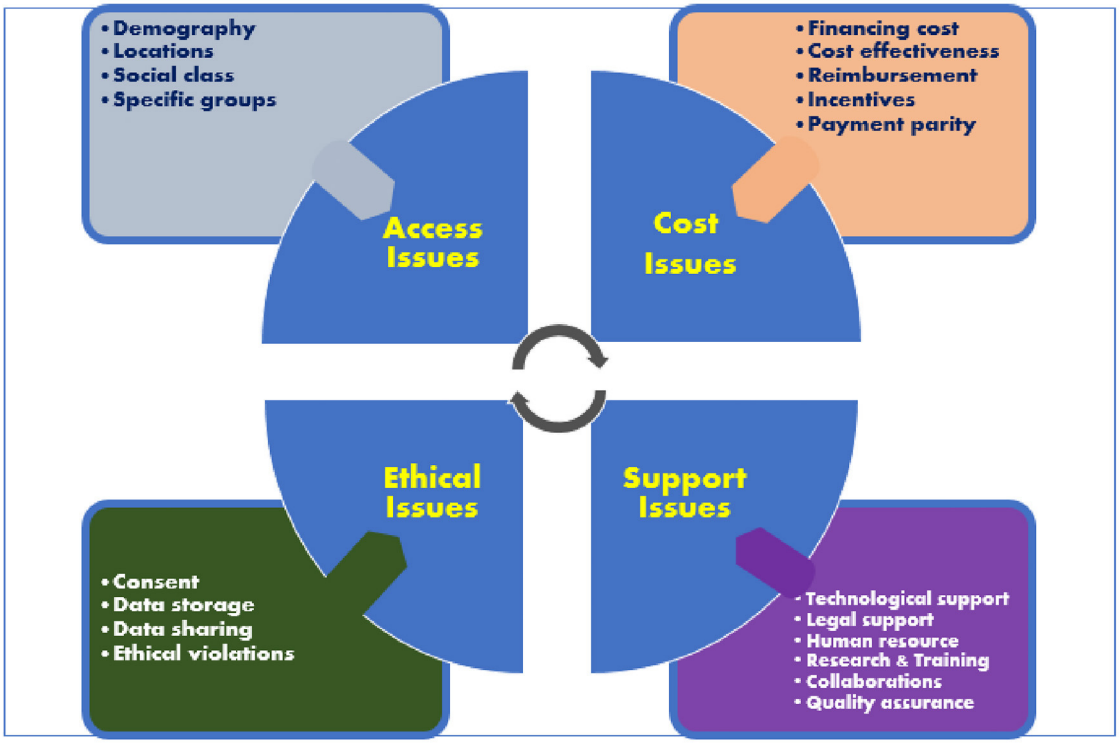

FIGURE 2 | ACES model for expansion of teleneurology services in Sub-Sahran Africa.

or underserviced hospitals. In the context of tele-neurology, the neurology specialists at the hub (an institution of health) will consult with doctors and people with neurologic symptoms at the remote sites (spokes) (52). The principles of task-shifting may be blended in this endeavor because health system development is still not even across SSA (53). The novel strategy of task-shifting has been shown to build relevant competencies among NPHW to bridge the human resource gap in the provision of services for non-communicable diseases such as HIV/AIDS and stroke. Our earlier reported experience with task-shifting for stroke recognition and care in southwestern Nigeria (53) indicates that this model is replicable for tele-neurology. The NPHW will require training and education to recognize common neurological disorders at remote sites and to co-ordinate with neurology specialists at the hub.

Costs

Although some extant literature has suggested that tele-neurology is not more cost-effective compared to conventional neurology service, especially with teleconsultation (54, 55), its long-time cost-effectiveness has now been established (56, 57). In most SSA countries, where a significant proportion of the population are not covered by health insurance, new tele-neurology services will need to demonstrate that people can get quality telehealth and tele-neurology services at cost-effective rates. Tele-health vendors will need to consider financing costs while institutions will need to ensure adequate remuneration and pay parity for physicians. While some schools of thought argue that telehealth and, by extension, tele-neurology services should be free-of-charge to be ethical and equitable, this healthcare delivery model is not without its challenges. Instead, a cost-effective model is advocated by other schools of thought (52). A free-of-charge tele-neurology service, if not adequately funded, can impede innovation in healthcare provision because such designs may not be incentivized. Besides, insufficient medical personnel staffing and a skewed doctor-patient ratio (a result of inadequate budgetary allocation and brain drain) can reduce care quality. For this model to be sustainable, countries in SSA need to increase the budget for health and retain sizeable professional stakeholders involved in tele-neurology service provision. In the context of improved budgetary allocation to health, the benefits of free-of-charge tele-neurology services can be realized. The gains of free-of-charge telehealth services include increase accessibility and affordability, an expanded range of tele-neurology services, and improved health-seeking behavior of the populace (58).

Ethics Issues

Privacy and data confidentiality will begin to take a central place as tele-neurology services advance. The current stakeholders and new service providers will need to address data storage (store and transfer) issues. Current regional or national data protection policies should be standardized and made applicable to tele-neurology services. Matters that may constitute a conflict-of-interest conundrum between stakeholders would need clear definitions from the outset. Data storage, sharing, and forwarding

would need to be governed by serious ethical guidelines. New tele-neurology programs must court patient's confidence by having a robust privacy and security plan that should be communicated to the patients (59).

Supports

All the stages of tele-neurology development require adequate support. The preparatory stage requires adequate support for and by the stakeholders which is made up of a multidisciplinary team (administrative staff, neurologists, other specialists, policymakers, telemedicine vendors, and ICT maintenance team). Telemedicine vendors would need to ensure network coverage in geographically isolated rural areas. Policymakers would need to be convinced that investments in telemedicine technology, improved connectivity, infrastructure, and network personnel are justified. Legal support is equally required, as are other supports provided by data-driven initiatives that research, development, and training stimulate. Finally, standards would need to be created for the engagement, training, and supervision of tele-neurology providers like what obtains in conventional practice to assure quality assurance and system organization. This multifaceted support system will ensure the sustainability of new tele-neurology services in SSA (60).

CONCLUSION

Certainly, telemedicine and tele-neurology services are still in their infancy in SSA. The exigency created by the COVID-19 pandemic is a wake-up call to institutions, countries, and indeed, heath authorities in SSA to redefine their posturing to telehealth, including tele-neurology. The proposed ACES model may ensure the sustainability of tele-neurology services in the SSA region beyond COVID-19. Improvement in systemic issues such as infrastructure and political will would play a key role in building and sustaining tele-neurology services in the SSA subcontinent (5, 30).

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

PA conceived the idea of the manuscript. PA, OO, and FT drafted the manuscript. All authors reviewed the manuscript for intellectual content and approved the final manuscript.

REFERENCES

1. Snohomish Health District. *COVID-19 General Information*. Snohomish Health District, WA (2020). Available online at: https://www.snohd.org/495/COVID-19-General-Information (accessed June 15, 2020).
2. Worldometer. Coronavirus cases. *Worldometer*. (2020) 2020:1–22. doi: 10.1101/2020.01.23.20018549V2
3. Robertson FC, Lippa L, Broekman MLD. Editorial. Task shifting and task sharing for neurosurgeons amidst the COVID-19 pandemic. *J Neurosurg*. (2020) 2020:1–3. doi: 10.3171/2020.4.jns201056
4. Minni A, Ralli M, Candelori F, Cialente F, Ercoli L, Parlapiano C, et al. Lessons learned from COVID-19 pandemic in Italy. *Bosn J Basic Med Sci*. (2020). doi: 10.17305/bjbms.2020.4847. [Epub ahead of print].
5. Bhaskar S, Bradley S, Israeli-Korn S, Menon B, Chattu VK, Thomas P, et al. Chronic neurology in COVID-19 era: clinical considerations and recommendations from the REPROGRAM Consortium. *Front Neurol.* (2020) 11:664. doi: 10.3389/fneur.2020.00664
6. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) settings: recommendations from the REPROGRAM Consortium. *Front Cardiovasc Med*. (2020) 7:112. doi: 10.3389/fcvm.2020.00112
7. Bhaskar S, Sharma D, Walker AH, McDonald M, Huasen B, Haridas A, et al. Acute neurological care in the COVID-19 era: the pandemic health system resilience PROGRAM (REPROGRAM) Consortium Pathway. *Front Neurol.* (2020) 11:579. doi: 10.3389/fneur.2020.00579
8. Siegler JE, Heslin ME, Thau L, Smith A, Jovin TG. Falling stroke rates during COVID-19 pandemic at a Comprehensive Stroke Center: cover title: falling stroke rates during COVID-19. *J Stroke Cerebrovasc Dis*. (2020) 2020:104953. doi: 10.1016/j.jstrokecerebrovasdis.2020.104953
9. The Aga Khan University News. *COVID-19: Innovative ways of delivering neurological healthcare*. The Aga Khan University News. Available online at: https://www.aku.edu/news/Pages/News_Details.aspx?nid=NEWS-002139 (accessed June 6, 2020).
10. Odusote KA, Ogunniyi A. Development of a clinical neurology workforce in West Africa. *Archive of Ibadan Med*. (2009) 10:7–12.
11. Ganapathy K. Telemedicine and neurological practice in the COVID-19 era. *Neurol India.* (2020) 68:555–9. doi: 10.4103/0028-3886.288994
12. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system resilience PROGRAM (REPROGRAM) International Consortium (Part 2). *Front Public Heal.* (2020) 8:410. doi: 10.3389/fpubh.2020.00410
13. Petrazzini B, Kibati M. The internet in developing countries. *Commun ACM*. (1999) 42:31–6. doi: 10.1145/303849.303858
14. Ajakaiye O, Ncube M. Infrastructure and economic development in Africa: an overview. *J Afr Econ*. (2010) 19(Suppl.1):i3–12. doi: 10.1093/jae/ejq003
15. Mbarika VWA, Okoli C. Telemedicine in Sub-Saharan Africa: a proposed Delphi study. In: *Proc 36th Annu Hawaii Int Conf Syst Sci HICSS 2003*. Big Island, HI: IEEE (2003). p. 1–9. doi: 10.1109/HICSS.2003.1174373
16. TSA. What is telehealth? *What is Telehealth?* (2014) 2014:1. doi: 10.1056/CAT.18.0268
17. Larner AJ. Teleneurology: an overview of current status. *Pract Neurol*. (2011) 11:283–8. doi: 10.1136/practneurol-2011-000090
18. Patterson V. Teleneurology. *J Telemed Telecare*. (2005) 11:55–9. doi: 10.1258/1357633053499840 PMID: 15829048.
19. UNFPA - United Nations Population Fund. *Population and Development in Africa*. Available online at: https://www.unfpa.org/resources/population-and-development-africa (accessed June 16, 2020).
20. Data. *Rural population (% of total population) - Sub-Saharan Africa*. Available online at: https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ZG (accessed June 16, 2020).
21. World Health Organization (WHO). *Health Systems in Africa: Community. Perceptions and Perspectives*. Available Online at: https://www.afro.who.int/publications/health-systems-africa-community-perceptions-and-perspectives (accessed January 8, 2021).
22. Matimba A, Woodward R, Tambo E, Ramsay M, Gwanzura L, Guramatunhu S. Tele-ophthalmology: opportunities for improving diabetes eye care in resource- and specialist-limited Sub-Saharan African countries. *J Telemed Telecare.* (2016) 22:311–6. doi: 10.1177/1357633X15604083
23. Forrest JI, Wiens M, Kanters S, Nsanzimana S, Lester RT, Mills EJ. Mobile health applications for HIV prevention and care in Africa. *Curr Opin HIV AIDS.* (2015) 10:464–71. doi: 10.1097/COH.0000000000000198

24. Adjorlolo S. Can teleneuropsychology help meet the neuropsychological needs of Western Africans? the case of Ghana. *Appl Neuropsychol.* (2015) 22:388–98. doi: 10.1080/23279095.2014.949718
25. Chipps J, Ramlall S, Mars M. Practice guidelines for videoconference-based telepsychiatry in South Africa. *African J Psychiatry.* (2012) 15:271–82. doi: 10.4314/ajpsy.v15i4.35
26. Sangaré M, Tanner L, Voss S, Laureys F, Hollow D, Touré M. A national teleradiology programme in Mali: implementation and results. *J Telemed Telecare.* (2015) 21:131–8. doi: 10.1177/1357633X15569966
27. Lipoff JB, Cobos G, Kaddu S, Kovarik CL. The Africa teledermatology project: a retrospective case review of 1,229 consultations from sub-Saharan Africa. *J Am Acad Dermatol.* (2015) 72:1084–5. doi: 10.1016/j.jaad.2015.02.1119
28. Jithoo R, Govender P V., Corr P, Nathoo N. Telemedicine and neurosurgery: experience of a regional unit based in South Africa. *J Telemed Telecare.* (2003) 9:63–6. doi: 10.1258/135763303321327894
29. Bagayoko CO, Niang M, Anne A, Traoré D, Sangho H, Traoré A-K, et al. The delegation of tasks in the era of e-health to support community interventions in maternal and child health: lessons learned from the PACT-Denbaya project. *Med Sante Trop.* (2017) 27:354–9. doi: 10.1684/mst.2017.0727
30. Leone M, Corsi FM, Ferrari F, Thole D, Didato G, Marazzi MC, et al. Teleneurology in sub-Saharan Africa: experience from a long lasting HIV/AIDS health program (DREAM). *J Neurol Sci.* (2018) 391:109–11. doi: 10.1016/j.jns.2018.06.013
31. The First Arab African Teleneurology. *The First Arab African Teleneurology Conference: A Treat and Teach Initiative*. (2020). Available online at: https://worldneurologyonline.com/article/the-first-arab-african-teleneurology-conference-a-treat-and-teach-initiative/ (accessed December 12, 2020).
32. ASUVH. *The African Movement Disorders Grand Round: Multicenter Webinar Series ASUVH*. (2020). Available online at: http://www.asuvh.com/ (accessed December 18, 2020).
33. Wamala D, Augustine K. A meta-analysis of telemedicine success in Africa. *J Pathol Inform*. (2013) 4:6. doi: 10.4103/2153-3539.112686
34. Ovbiagele B. Phone-based intervention under nurse guidance after stroke: concept for lowering blood pressure after stroke in Sub-Saharan Africa. *J Stroke Cerebrovasc Dis*. (2015) 24:1–9. doi: 10.1016/j.jstrokecerebrovasdis.2014.08.011
35. Nichols M, Sarfo FS, Singh A, Qanungo S, Treiber F, Ovbiagele B, et al. Assessing mobile health capacity and task shifting strategies to improve hypertension among ghanaian stroke survivors. *Am J Med Sci.* (2017) 354:573–80. doi: 10.1016/j.amjms.2017.08.005
36. Valdes Angues R, Suits A, Palmer VS, Okot C, Okot RA, Atonywalo C, et al. A real-time medical cartography of epidemic disease (Nodding syndrome) using village-based lay mHealth reporters. *PLoS Negl Trop Dis.* (2018) 12:e0006588. doi: 10.1371/journal.pntd.0006588
37. Cubo E, Doumbe J, López E, Lopez GA, Gatto E, Persi G, et al. Telemedicine enables broader access to movement disorders curricula for medical students. *Tremor Other Hyperkinet Mov*. (2017) 7:501. doi: 10.7916/D8708CXW
38. Cubo E, Doumbe J, Njiengwe E, Onana P, Garoa R, Alcalde J, et al. Parkinson's disease tele-education program for health care providers in Cameroon. *J Neurol Sci.* (2015) 357:285–7. doi: 10.1016/j.jns.2015.07.019
39. Sarfo FS, Adamu S, Awuah D, Sarfo-Kantanka O, Ovbiagele B. Potential role of tele-rehabilitation to address barriers to implementation of physical therapy among West African stroke survivors: a cross-sectional survey. *J Neurol Sci*. (2017) 381:203–8. doi: 10.1016/j.jns.2017.08.3265
40. Adebayo PB, Jusabani A, Mukhtar M, Zehri AA. The changing trend of teleconsultations during COVID-19 era at a tertiary facility in Tanzania. *Pan Afr Med J.* (2020) 35(Suppl.2):24977. doi: 10.11604/pamj.supp.2020.35.2.24977
41. Kuchenbuch M, d'Onofrio G, Wirrell E, Jiang Y, Dupont S, Grinspan ZM, et al. An accelerated shift in the use of remote systems in epilepsy due to the COVID-19 pandemic. *Epilepsy Behav.* (2020) 112:107376. doi: 10.1016/j.yebeh.2020.107376
42. Sarfo FS, Adamu S, Awuah D, Ovbiagele B. Tele-neurology in sub-Saharan Africa: a systematic review of the literature. *J Neurol Sci.* (2017) 380:196–9. doi: 10.1016/j.jns.2017.07.037
43. Kenyan Wallstreet. *Kenya's Mobile Phone Penetration Surpasses 100% Mark*. (2020). Available online at: https://kenyanwallstreet.com/kenyas-mobile-phone-penetration-surpasses-100-mark/ (accessed December 18, 2020).
44. Internet Mobile and Broadband African Reports. *Africa Telecommunications Reports*. (2020). Available online at: https://www.internetworldstats.com/africa2.htm (accessed June 16, 2020).
45. Geissbuhler A, Ly O, Lovis C, L'Haire JF. Telemedicine in Western Africa: lessons learned from a pilot project in Mali, perspectives and recommendations. *AMIA Annu Symp Proc*. (2003) 2003:249–53.
46. Clyde & Co (en). *COVID-19 South Africa: Pandemic and Telemedicine*. (2020). Available online at: https://www.clydeco.com/insight/article/covid-19-south-africa-pandemic-and-telemedicine (accessed June 16, 2020).
47. Ebenso B, Allsop MJ, Okusanya B, Akaba G, Tukur J, Okunade K, et al. Impact of using eHealth tools to extend health services to rural areas of Nigeria: protocol for a mixed-method, non-randomised cluster trial. *BMJ Open*. (2018) 8:22174. doi: 10.1136/bmjopen-2018-022174
48. Wootton R, Hebert MA. What constitutes success in telehealth? *J Telemed Telecare*. (2001) 7(suppl.2):3–7. doi: 10.1258/1357633011937245
49. Mummery CJ, Kipps CM. UK neurology response to the COVID-19 crisis. *Clin Med*. (2020) 20:266–9. doi: 10.7861/CLINMED.2020-0159
50. McGinley MP, Ontaneda D, Wang Z, Weber M, Shook S, Stanton M, et al. Teleneurology as a solution for outpatient care during the COVID-19 pandemic. *Telemed J E Health*. (2020) 16:137. doi: 10.1089/tmj.2020.0137
51. Bergen DC. World Federation of Nuerology Task Force on Neurological Services. Training and distribution of neurologists worldwide. *J Neurol Sci*. (2002) 198:3–7. doi: 10.1016/s0022-510x(02)00071-0
52. Wechsler LR, Tsao JW, Levine SR, Swain-Eng RJ, Adams RJ, Demaerschalk BM, et al. Teleneurology applications: report of the telemedicine work group of the American Academy of Neurology. *Neurology*. (2013) 80:670–6. doi: 10.1212/WNL.0b013e3182823361
53. Akinyemi RO, Owolabi MO, Adebayo PB, Akinyemi JO, Otubogun FM, Uvere E, et al. Task-shifting training improves stroke knowledge among Nigerian non-neurologist health workers. *J Neurol Sci*. (2015) 359:112–6. doi: 10.1016/j.jns.2015.10.019
54. Chua R, Craig J, Wootton R, Patterson V. Cost implications of outpatient teleneurology. *J Telemed Telecare*. (2001) 7(suppl.1):62–4. doi: 10.1177/1357633x010070s126
55. Craig J, Chua R, Russell C, Patterson V, Wootton R. The cost-effectiveness of teleneurology consultations for patients admitted to hospitals without neurologists on site. 1: A retrospective comparison of the case-mix and management at two rural hospitals. *J Telemed Telecare*. (2000) 6(suppl.1):1357. doi: 10.1258/1357633001934122
56. Neurology Advisor. *The Evolution of Care and Cost in Teleneurology*. (2020). Available online at: https://www.neurologyadvisor.com/topics/general-neurology/the-evolution-of-care-and-cost-in-teleneurology/ (accessed December 18, 2020).
57. Kadel R, Evans-Lacko S, Tramarin A, Stopazzolo G. Cost-effectiveness of tele-video-consultation for the neuro-surgical emergency management at the general hospitals in Italy. *Front Neurosci.* (2018) 12:908. doi: 10.3389/fnins.2018.00908
58. Kandie Lynn. *Advantages and disadvantages of free health care*. Available online at: https://briefly.co.za/47269-advantages-disadvantages-free-health-care.htmlhttps://briefly.co.za/47269-advantages-disadvantages-free-health-care.html (accessed October 18, 2020).
59. Mehta SJ. Telemedicine's potential ethical pitfalls. *Virtual Mentor*. (2014) 16:1014–7. doi: 10.1001/virtualmentor.2014.16.12.msoc1-1412
60. Telemedicine. Available online at: https://www.aan.com/policy-and-guidelines/policy/position-statements/telemedicine/ (accessed June 11, 2020).

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Virtual Reality as a Technological-Aided Solution to Support Communication in Persons With Neurodegenerative Diseases and Acquired Brain Injury During COVID-19 Pandemic

Fabrizio Stasolla[1], Marta Matamala-Gomez[2], Sara Bernini[3], Alessandro O. Caffò[4] and Sara Bottiroli[1,3]*

[1] "Giustino Fortunato" University of Benevento, Benevento, Italy, [2] Department of Human Sciences for Education "Riccardo Massa", Center for Studies in Communication Sciences "Luigi Anolli" (CESCOM), University of Milano-Bicocca, Milan, Italy, [3] Scientific Institute for Research, Hospitalization, and Healthcare (IRCCS), Mondino Foundation, Pavia, Italy, [4] Department of Educational Sciences, Psychology and Communication, University of Bari, Bari, Italy

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***Correspondence:**
Fabrizio Stasolla
f.stasolla@unifortunato.eu

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The COVID-19 poses an ongoing threat to lives around the world and challenges the existing public health and medical service delivery. The lockdown or quarantine measures adopted to prevent the spread of COVID-19 has caused the interruption in ongoing care and access to medical care including to patients with existing neurological conditions. Besides the passivity, isolation, and withdrawal, patients with neurodegenerative diseases experience difficulties in communication due to a limited access to leisure opportunities and interaction with friends and relatives. The communication difficulties may exacerbate the burden on the caregivers. Therefore, assistive-technologies may be a useful strategy in mitigating challenges associated with remote communication. The current paper presents an overview of the use of assistive technologies using virtual reality and virtual body ownership in providing communication opportunities to isolated patients, during COVID-19, with neurological diseases and moderate-to-severe communication difficulties. We postulate that the assistive technologies-based intervention may improve social interactions in patients with neurodegenerative diseases and acquired brain injury-thereby reducing isolation and improving their quality of life and mental well-being.

Keywords: assistive technology, neurodegenerative diseases, healthcare, COVID19, quality of life, caregivers burden

INTRODUCTION

Persons with neurodegenerative diseases and acquired brain injuries may fail while dealing with everyday life environmental requests. Their independence, social interactions, communication skills, and functional activities may be seriously hampered with deleterious effects on their quality of life (1–3). Isolation, passivity, and detachment may be observed with negative outcomes on caregivers and families' burden (4–6).

Both intellectual and motor impairments may emerge with a significant reduction of an overall individual's functioning (7, 8). To be effective, a rehabilitative intervention should be implemented early regarding brain damage and should be intensive and assiduously prolonged over the time. Moreover, to be consolidated and generalized, the learning process should be pursued across settings (9, 10). Unfortunately, COVID-19 pandemic relevantly impeded the implementation and the realization of those conditions (11, 12). In fact, by December 24, 2020, over 72 million of cases have been documented worldwide, with almost 1.7 million of deaths (13, 14). Quarantine and social distancing interrupted public health services and regular medical care delivery (15). Public health preventions have centered around social-distancing, masks, and hand-washing strategies. Patients with chronic neurodegenerative diseases (e.g., Alzheimer, Parkinson, amyotrophic lateral sclerosis), demyelinating diseases as multiple sclerosis, and persons with acquired brain injuries (e.g., stroke, post-coma) have been impacted by lockdowns—making them vulnerable during the COVID-19 (16). In order to deal with these issues, one may envisage assistive technology (AT)-based strategies (17, 18).

AT options are broadly recognized as crucial means of support for individuals with neurodegenerative diseases and acquired brain injuries and multiple disabilities (19). Thus, AT-based programs are commonly planned to favorably fill the gap between behavioral/cognitive skills and environmental requests (20). That is, an AT setup is conceived to build functional bridges between users, environment, and technology. Essentially, it ensures that a helpful interaction (i.e., purposeful behavior and goal-oriented) is achieved for persons with extensive motor delays (21). That interaction is critical to enhancing personal fulfillment, social image, active role, satisfaction, and improving quality of life accordingly (22). Among different targeted areas, communication and leisure opportunities have been promoted (23–25). Scopus database emphasizes different empirical contributions which demonstrate the relevance and the beneficial effects on practical daily issues (e.g., communication, leisure, internet access) of technology-based programs in individuals with neurodegenerative diseases and acquired brain injuries (26–32).

At present, striking changes for public health and medical delivery services have been determined by COVID-19, including the need to find alternative solutions to take action against the substantial interruption of the regular medical care assistance and to social distance limitations forced by this pandemic (33–36). The main goal of this article is to propose a perspective on a new AT-based approach in using VR and virtual body ownership illusions to enable the communication of the patients with neurological diseases and severe-to-profound disabilities in case of isolation inside the hospital or in his/her home during this pandemic situation. In this context, current evidence-based recommendations on the use of AT-based strategies, including virtual reality (VR), as technological-aided solutions to support communication and leisure in neurological disorders, will be explored. **Table 1** summarizes some relevant examples of AT-based and VR solutions for both targeted populations.

COMMUNICATION AND LEISURE IN NEUROLOGICAL DISORDERS

Failure to positively engage in communication and leisure activities includes the incapacity to handle social interactions independently and profitably. For instance, individuals with neurodegenerative diseases and acquired brain injuries and multiple disabilities may be unable to undertake and pursue leisure activities autonomously, that is, they remain dependent on both families and caregivers. Additionally, people with neurological impairments may be unable to adequately communicate their needs or favorably make requests and choose desired items. Moreover, people with neurological impairments may face difficulties in communicating with distant partners (37, 46, 47). Technological-aided setups may be viewed as helpful supports focused on filling the existing gap between the actual individual's skills and the skill level necessary to achieve functional objectives. Accordingly, AT-based devices, setups, and tools should be rigorously customized in terms of (a) personal skills and (b) meaningful goals to be useful (48). For instance, whenever the individual has extensive motor disorders and lack of speech but is estimated within a normal range of intellectual functioning (e.g., multiple sclerosis), one may design technological aids aimed at helping the patients perform different adaptive responses. Practically, with the AT-based intervention, persons with neurodegenerative diseases and acquired brain injuries and significant impairments may be helped (a) to make small adaptive responses available in their behavioral repertoire and (b) to use adaptive responses to achieve functional tasks and/or pursue meaningful purposes (49). Communication or leisure opportunities or their combination could be embedded in a rehabilitation program using AT (39, 40, 50). Moreover, communication with distant partners through short text messages, telephone calls, or video-calls may be implemented to promote social interactions (51, 52). For instance, (53) the newly developed high-sensitivity mechanical switch for augmentative and alternative communication access in people with amyotrophic lateral sclerosis, namely the Lever Magnetic-spring Mechanical Switch (i.e., LeMMS). Results of the validation study evidenced that all the participants were capable to operate the LeMMS, which could help these patients to communicate even in an advanced stage of the disease.

INTERNET-BASED COMMUNICATION IN NEUROLOGICAL DISORDERS

Internet-based communication has revealed a useful transformative medium for overcoming traditional barriers to delivering healthcare services at patients' homes (38). Through internet-based communication services, it is possible to establish direct communication with the patients and their caregivers despite the distance. The increasing availability of internet access has already changed healthcare delivery and communication routines among patients, caregivers, and clinicians (54). Mental health difficulties are commonly documented across neurological disorders. Moreover, meta-analysis reported high

TABLE 1 | Studies integrating AT-based and VR solutions to improve communication in individuals with neurodegenerative diseases and acquired brain injuries.

References	Aim of the study	Patients (Type)	Intervention	Technology (Type)	Main outcomes
AT-based solutions					
Lancioni et al. (17)	To study an extended smartphone-aided program that supported daily activities in addition to communication and leisure in individuals with intellectual and visual or visuo-motor disabilities	*N* = 6 participants with visual or hearing impairment. Age = between 35 and 58 years old	The participants alternated periods in which they could engage in communication and leisure with periods in which they were provided with instructions for daily activities	The extended program relied on the use of a Samsung Galaxy J4 Plus smartphone, which was fitted with Android 9.0 operating system and MacroDroid	After using the smartphone application, participants maintained successful communication and leisure engagement and started and carried out daily activities successfully
Lancioni et al. (37)	To assess an upgraded smartphone-based program to foster independent leisure and communication activity of participants with mild to moderate intellectual disability, sensory or sensory-motor impairments, and limited speech skills	*N* = 8 participants with visual or hearing impairment. Age = between 35 and 58 years old	Participants conducted leisure and communication activities by placing mini objects or pictures representing those activities and containing frequency-code labels on the smartphone. The smartphone, via the Macrodroid application, discriminated the participants' requests and provided them with the requested activities	The program was based on the use of (a) a Samsung Galaxy A3 smartphone with Android 6.0 Operating System, near-field communication, music and video player functions, and Macrodroid application, and (b) special radio frequency-code labels	After using the smartphone application, participants succeeded in requesting/accessing those activities independently and spent about 70–90% of their session time busy with those activities
Comer et al. (38)	To present an Internet-delivered Parent-Child Interaction therapy (PCIT) directly to families in their own home	Not applicable (methods article)	Not applicable (methods article)	Two computers (one in the therapist office and one in the family's home). A webcam. High-speed Internet connection	Internet-based delivery of PCIT (I-PCIT) may offer a transformative medium for overcoming traditional barriers to care. I-PCIT therapists provide remote, real-time coaching to parents during home-based parent-child interactions
Lancioni et al. (39)	To assess (a) the usability and effectiveness of the technology that allows the person to access a variety of stimulus events (e.g., songs and videos), to request caregiver's functional procedures, and to communicate with relevant partners via text messaging, and (b) the potential impact of the simultaneous availability of these technologies, in 2 post-coma persons who had emerged from a minimally conscious state and were affected by multiple disabilities	*N* = 2 participants emerged from a minimally conscious state and affected by multiple disabilities. A woman and a man of 44 and 24 years of age, respectively	The participants had to select different options within a computer program in order to access to a variety of pleasant stimuli, to request caregiver's functional procedures, and to communicate with relevant partners via text messaging. Such options were selected throughout a microswitch, which was triggered by a behavioral response and that in turn activated the choice process within the computer program	Leisure stimulus engagement and procedure requests: portable computer with commercial software, a microswitch for the participants' response, and an interface connecting the microswitch to the computer. Text messaging communication: portable computer, a GSM modem, a microswitch for the participants' response, an interface connecting the microswitch to the computer, and specifically developed software	The participants were successful at each of the three stages of the study, thus providing relevant evidence concerning performance achievements
Lancioni et al. (40)	To allow persons with multiple disabilities to (a) write and send messages to distant partners and (b) have messages from those partners read out to them	*N* = 2 women with multiple disabilities due to complications during the gestational period and to a mild form of Joubert syndrome, aged 31 and 22 years old, respectively	The participants had to select different options within a computer program in order to write and send text messages to distant partners and to have them read from such partners	A net-book computer connected to the special keyboards arranged for the two participants, a global system for mobile communication modem (GSM), a pressure microswitch to activate the computer, interfaces linking the microswitch and the GSM modem to the computer, and a specifically developed software program	The special text messaging communication system enabled the two participants to successfully communicate with distant partners, and both participants were able to write their text messages through the technology options (i.e., the special keyboards) adopted for them

(Continued)

TABLE 1 | Continued

References	Aim of the study	Patients (Type)	Intervention	Technology (Type)	Main outcomes
VR-based solutions					
Isernia et al. (41)	To report results on efficiency measures and perceived functioning in real world of the Human Empowerment Aging and Disability program (HEAD), a DH-telerehabilitation system for people with chronic neurological diseases	*N* = 107 patients with Parkinson's Disease, Multiple Sclerosis, and chronic stroke. Age = between 18 and 80 years old	Patients received a 3-month rehabilitation training at home	A computer. Internet connection and motor capture devices, such as Kinect (Microsoft, WA, USA) and Leap Motion (Leap Motion Inc., CA, USA). Virtual reality scenario	The telehealth-based approach is both feasible and efficient in providing rehabilitation care to the patients from clinic to home. Increasing and maintaining participation as well as autonomy in daily routine
Baker et al. (42)	To investigate how 3D virtual environments can support social experiences in older adults	*N* = 25 older adults. Age = between 70 and 81 years old	The older adults participated in three workshops that allowed them to experience core aspects of social VR, in which they could design their own virtual avatars	Virtual avatars projected on a 180-degree semi-circular screen (workshop 2). Two Microsoft Kinect 3D cameras in each room were used to track participants' movement. Head-mounted display provided virtual embodiment (workshop 3)	The results from the workshops provide insight into older adults' design motivations when creating embodied avatars for social VR; their acceptance of social VR as a communication tool; and their views on how social VR might play a beneficial role in their lives. Participants placed critical importance on behavioral anthropomorphism—the embodied avatars' ability to speak, move, and act in a human-like manner
Slater et al. (43)	To investigate whether a body swapping to a Freud virtual body, where participants attempted to resolve their problem using their own words from two different embodied perspectives, or whether a conversation in which they talk about their problem with a pre-programmed animated virtual Freud would be equally efficacious in producing positive psychological outcomes	*N* = 69 healthy subjects. Age = between 18 and 32 years old	Participants alternating between being embodied in their own and the Freud virtual body while maintaining a self-dialogue, as if between two different people	Digital scanning set-up: iPad equipped with a structured light range sensor + inverse kinematics techniques the upper body movements of the participants could be inferred and mapped to their virtual representation. Vive head-mounted-display (HMD) made by HTC that displays a 3D scene	The results showed that the Self-Conversation method results in a greater perception of change and help compared to having a conversation with a virtual Sigmund Freud
Osimo et al. (44)	To observe how participants alternately switched between a virtual body closely resembling themselves where they described a personal problem and a VB representing Dr Sigmund Freud, from which they offered themselves counseling	*N* = 22 healthy subjects (males). Age = between 23 and 24 years old	Participants alternately switched between a virtual body closely resembling themselves where they described a personal problem and a VB representing Dr Sigmund Freud	The head-mounted display used was the Oculus DK2. Participants wore an XSens MVN motion capture suite consisting of the MVN Link 17 tracker tracking suit and MVN Studio software to stream motion data. Software Skanect (http://skanect.occipital.com/) version 1.6 to acquire the whole body scan	Counselor resembles Freud participants improve their mood, compared to the counselor being a self-representation. The improvement was greater when the Freud virtual body moved synchronously with the participant, compared to asynchronously visuo-motor coordination
Perez-Marcos et al. (45)	To propose an integrated approach that includes three key and novel factors: (a) fully immersive virtual environments, including virtual body representation and ownership; (b) multimodal interaction with remote people and virtual objects including haptic interaction; and (c) a physical representation of the patient at the hospital through embodiment agents (e.g., as a physical robot)	Not applicable (methods article)	Not applicable (methods article)	A Head-mounted display with head-tracking for immersion in the virtual environment from a first-person perspective of the avatar representing him. A wireless body tracking system for controlling over the avatar's movements. A haptic device with force-feedback is used for tactile interaction with the environment and/or remote persons. Physiological sensors and electrodes for monitoring the patients' physiological and emotional state	This unique system for telerehabilitation is the result of the integration of state of the art technologies developed at different institutions in the fields of VR, haptics, computer science, biomedical research, and neuroscience. This approach systematically differs from non-immersive telerehabilitation systems and should represent a step forward in the field

anxiety and depression levels among individuals with multiple sclerosis, Parkinson's disease, and acquired brain injuries (55). Across neurological diseases, poor mental health is linked to poor quality of life, greater disability, poor prognosis and disease improvement, poor benefits after intervention (56). Accordingly, some studies have demonstrated that improving social communication in patients presenting neurodegenerative diseases and acquired brain injuries may improve their quality of life (57). Indeed, the relationship between verbal communication ability and quality of life has been shown. In detail, initial speech impairment in patients with neurodegenerative diseases and acquired brain injuries have a strong impact on their quality of life (58).

Internet connections are crucial to ensure people with timely social interactions, general public awareness, enhanced health conditions, specific knowledge on otherwise less-known neurological diseases, and health-related coping (59). Patients with neurological impairments can easily find numerous opportunities for peer social connections, learning, and leisure options (60). Furthermore, neurologists can easily manage user-generated data to satisfactory have an exhaustive representation of patients' needs and carry out epidemiological investigations (61). For example, a recent study (60) explored when and how technology could help interactions among patients with dementia and their caregivers. Three dyads patient-caregiver living in their homes were equipped with tablet computers and web-based applications and researchers analyzed their interactions. The study outlined benefits in terms of dyad interaction derived from the use of technology, suggesting the importance of an adequate provision of technology-based equipment for individuals with dementia.

Telerehabilitation (TR) offers a medium to deliver rehabilitation services and manage patients remotely using technology-based information and communication (61, 62). The adopted technologies may broadly include emails, data transmissions through videos and/or photos sent by the health provider or the user or both (63). Additionally, tablets and computers, internet-based media or programs, video conferencing, smartphones, and webinars are usually embedded (64). Typically, TR may be adopted as synchronous (i.e., the health provider and user are simultaneously connected) or as asynchronous (i.e., the health provider and user are not simultaneously connected but connected through stored data and virtual technologies or electronic communication) (41, 65). Currently, one of the newest technologies used to engage patients and caregivers in the TR training is VR systems (65, 66).

TELEPRESENCE AND VIRTUAL REALITY

At the end of the last century, VR constitutes the evolution of the old communication interfaces such as telephone, computer, and television toward the emergence of the integration of different data coming from different modalities (67). According to this, Biocca and Levy (68) defined VR as a communication system instead of a piece of technology (69). Then, VR is a communication interface connecting: (1) physical media, (2) codes, (3) information, and (4) sensorimotor channels (69). A main characteristic of VR is that allows the full immersion of the human sensorimotor channels into a vivid and realistic communication experience (68). In fact, VR is a successor of internet-based communication (70). Essentially, VR represents a technology through which it is possible to simulate existing experiences into a fake immersive virtual environment (71). Immersion is related to the extent to which the VR systems can deliver an inclusive, extensive, surrounding, and vivid illusion of reality to the participant's sensory senses. Then, immersion corresponds to the objective and quantifiable description of what the technology can provide (72). For instance, some studies demonstrated the use of VR systems, such as wearable headsets and 3-D smart televisions, to provide enjoyable, leisurely activities, with benefits in terms of quality of life, psychological well-being, and facilitated social interactions in patients with cognitive impairment (73). One example is a VR intervention using a virtual environment displayed on two large screens with head-mounted 3-D glasses and body-tracking sensors to promote engagement in patients with Mild Cognitive Impairment (74).

Another main feature of the VR system is the capability to induce a sense of "presence" into the virtual environment, which corresponds to the psychological perception of being in the virtual environment (72, 75). However, as described by Schroeder in 1996: "The notion of communications technology normally implies two or more people are involved and the emphasis is placed on the messages that pass between them" (p. 146) (76). In this regard, VR allows the possibility to interact with the immersive virtual environment and different virtual characters or avatars (77). Through VR, it is also possible to induce the sense of co-presence, that is the sense of being together in a shared space, combining significant characteristics of being both physically and socially present (78). According to this, it has been argued that the validity of the telepresence depends on the capacity to produce a context in which social actors, or social avatars in the case of VR, may communicate and cooperate between them (79–81). In line with this definition of telepresence, a large number of investigations induced telepresence within a virtual environment by means of virtual body ownership illusions (82–84). In these experimental studies, the researchers induced the illusion, by using synchronous visuo-tactile stimulation of being in the embodied virtual body instead than in the real one, inducing the sense of telepresence among the participants (82–84). Due to the possibility of moving subjects from one place to another when using VR systems, telepresence results as a promising strategy to facilitate communication with patients and their relatives when they are at home (45).

NEW COMMUNICATION TECHNOLOGIES: VIRTUAL REALITY AS A COMMUNICATION TOOL IN CLINICAL POPULATIONS

Based on the above-commented VR systems components, a recent study investigated how VR may contribute to older adult

well-being by facilitating greater social VR participation (42, 85). In detail, in the study from Baker and colleagues, the authors conducted three workshops in which 25 older adults aged from 70 to 81 used VR as a medium for communicating with other participants (42). Older adults had to create embodied virtual avatars controlled through natural gestures and subsequently successfully and effectively used these avatars in two social VR prototypes from a third- or a first-person perspective. In this line, others used VR as a communication tool allowing medical staff to virtually interact with a virtual avatar assistant to assess and treat a virtual avatar victim presenting clinical complications (86). Additionally, virtual medical interaction with the patients through virtual avatars and telepresence has also been proposed (45, 87–89). In detail, Perez-Marcos and colleagues presented an innovative VR set-up that allows remote interaction and rehabilitation, including both the patient and doctor body projection into virtual bodies in a fully immersive environment and the physical embodiment at the remote place (45).

According to these promising studies, here we propose a VR intervention to foster and facilitate social interactions with both the clinicians and relatives with virtual avatars and telepresence in patients with neurological disorders. Such an intervention could be used when patients are isolated due to their clinical condition or to the social distance limitations forced by the COVID-19 pandemic situation. The proposed intervention aims to improve the patient's well-being avoiding his/her isolation. Specifically, it is a new VR social intervention by means of full-body ownership illusions observed from a first-person perspective and delivered through a head-mounted display and the activation of a social VR application. The effectiveness of the VR social application for enhancing social interactions through virtual avatars has been previously shown in healthy individuals (90). The intervention aims to reproduce the patients' and their relatives' body representation within the same VR environment, that is a virtual living room. In this regard, the virtual avatars' anthropomorphism characteristics are important to further enhance the sense of ownership and increase the sense of presence in interaction with other virtual avatars (42, 43, 91). This intervention is composed of five different phases: (1) the creation of the virtual avatars by scanning patients' and relatives' real bodies as in the study conducted by Osimo and co-authors or in the study by Orts-Escolano and colleagues (44, 92); (2) the integration of such virtual avatars into the VR social application; (3) delivery and teaching to use the VR social application and the head-mounted display; (4) the creation of daily social VR appointments to meet and interact with the patient's relatives during isolation or hospitalization period; and (5) the creation of weekly social VR appointments between relatives and medical staff for an updating about patient's medical condition.

The proposed intervention may represent a solution to the current worldwide situation caused by the COVID-19 pandemic, which requires suitable and effective technology-based approaches. Many recommendations are indeed proliferating about the need of alternative strategies for delivering health care services in this contingency (33, 34, 93). If some months ago the focus was mainly on the treatment of COVID-19 patients (94–99), now a days we are assisting in a growing interest for alternative ways to support the process of care of non-COVID conditions, including patients with neurodegenerative diseases and acquired brain injuries (100–102). For instance, there are many evidences about the use of telemedicine—understood as an interface in a virtual patient-clinician relationship to provide primary and secondary care (62, 99–102)—and virtual reality for remote delivery of cognitive rehabilitation in various settings of neurological care (103–105). In this frame, we propose a VR-based intervention aimed to support another critical aspect of individual's functioning that is communication, in persons with neurodegenerative diseases and acquired brain injury during COVID-19 pandemic. Thus, by using an AT-implemented strategy such as VR interventions, patients with neurodegenerative diseases may be enabled to communicate his/her needs, feelings, and thoughts to their relatives or medical staff during the hospitalization or isolation period. Accordingly, it may be fostered with positive outcomes on his/her health conditions, with a meaningful reduction of the anxiety and/or depression levels, and with beneficial effects in terms of quality of life (106, 107). Therefore, the caregivers, families, and health care systems may find a significant burden reduction (108, 109). In conclusion, through this VR intervention for communication, the patients may (a) communicate their needs, (b) independently access leisure options (e.g., positive stimulation, favorite videos, amusing songs), and (c) be connected with distant relatives. Then, patients will be more engaged in communication, and with a purposeful behavior (110, 111). In this regard, the use of new technologies for fostering engagement in patients with neurodegenerative disorders has been demonstrated (65, 112, 113).

CONCLUDING REMARKS

The level of independence, social interactions, communication skills, and functional activities may be seriously hampered in patients with neurodegenerative diseases with deleterious effects on their quality of life (1–3). The isolation because of the COVID-19 pandemic situation may enhance such negative aspects with consequences on their quality of life (30, 114). To avoid that, some studies propose VR as a technologically-aided solution for clinical populations (99, 107, 115). However, most of these studies are focused on using VR to continue with the treatments and rehabilitation routines of the patients in case of isolation or social distancing. Depending on their level of functioning, persons with neurodegenerative diseases may be exposed to different aided-technological solutions to enhance communication skills. For example, individuals with extensive motor disabilities and moderate-to-severe intellectual disabilities may be involved in social interactions through vocal output communication aid (VOCA) or speech generating devices (SGD). Else, one may envisage hierarchical computerized systems with adapted software enabling patients with neurodegenerative diseases to request and choice desired items and/or communicate their

needs. Otherwise, for individuals estimated with an intellectual normal functioning and extensive motor impairments, the independent access to the literacy through computerized systems and keyboard emulators may be proposed. Moreover, during lockdown or quarantine imposed due to an infectious disease outbreak, one may consider the communication with a distant partner through technology-aided options including a smartphone and a global system for mobile communications (GSM) system (116, 117). Here we proposed a VR-AT solution to enable the communication among patients with neurodegenerative diseases or acquired brain injury, relatives, and medical staff during the COVID-19 pandemic situation. We hypothesized that this intervention may improve the patient's social interactions enhancing their quality of life and mental well-being, avoiding isolation and negative psychological and cognitive effects.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

FS, MM-G, and SBo have conceived the work. All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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REFERENCES

1. Heinrichs RW. The duality of human cognition: operations and intentionality in mental life and illness. *Neurosci Biobehav Rev*. (2020) 108:139–48. doi: 10.1016/j.neubiorev.2019.11.002
2. Zhu Y, Gao H, Tong L, Li ZL, Wang L, Zhang C, et al. Emotion regulation of hippocampus using real-time fMRI neurofeedback in healthy human. *Front Hum Neurosci*. (2019) 13:242. doi: 10.3389/fnhum.2019.00242
3. Kinney KL, Burkhouse KL, Klumpp H. Self-report and neurophysiological indicators of emotion processing and regulation in social anxiety disorder. *Biol Psychol*. (2019) 142:126–31. doi: 10.1016/j.biopsycho.2019.01.019
4. Rousseau MC, Baumstarck K, Valkov M, Felce A, Brisse C, Khaldi-Cherif S, et al. Impact of severe polyhandicap cared for at home on French informal caregivers' burden: a cross-sectional study. *BMJ Open*. (2020) 10:e032257. doi: 10.1136/bmjopen-2019-032257
5. Fleisher JE, Klostermann EC, Hess SP, Lee J, Myrick E, Chodosh J. Interdisciplinary palliative care for people with advanced Parkinson's disease: a view from the home. *Ann Cardiothorac Surg*. (2020) 9:S80–9. doi: 10.21037/apm.2019.09.12
6. Spencer L, Potterton R, Allen K, Musiat P, Schmidt U. Internet-based interventions for carers of individuals with psychiatric disorders, neurological disorders, or brain injuries: systematic review. *J Med Internet Res*. (2019) 21:e10876. doi: 10.2196/10876
7. Allen J, Molloy E, McDonald D. Severe neurological impairment: a review of the definition. *Dev Med Child Neurol*. (2020) 62:277–82. doi: 10.1111/dmcn.14294
8. Gardizi E, MacKillop E, Gaind G. Self-injurious behavior in a patient with dementia: a case report and literature review. *J Nerv Ment Dis*. (2019) 207:6–11. doi: 10.1097/NMD.0000000000000924
9. Zimmern V. Why brain criticality is clinically relevant: a scoping review. *Front Neural Circ*. (2020) 14:54. doi: 10.3389/fncir.2020.00054
10. Stevenson R, Samokhina E, Rossetti I, Morley JW, Buskila Y. Neuromodulation of glial function during neurodegeneration. *Front Cell Neurosci*. (2020) 14:278. doi: 10.3389/fncel.2020.00278
11. Szcześniak D, Gładka A, Misiak B, Cyran A, Rymaszewska J. The SARS-CoV-2 and mental health: from biological mechanisms to social consequences. *Prog Neuro Psychopharmacol Biol Psychiatry*. (2020) 104:110046. doi: 10.1016/j.pnpbp.2020.110046
12. Wilson BA, Betteridge S, Fish J. Neuropsychological consequences of Covid-19. *Neuropsychol Rehabil*. (2020) 30:1625–8. doi: 10.1080/09602011.2020.1808483
13. Hadi AG, Kadhom M, Hairunisa N, Yousif E, Mohammed SA. A review on COVID-19: origin, spread, symptoms, treatment, and prevention. *Biointerface Res Appl Chem*. (2020) 10:7234–42. doi: 10.33263/BRIAC106.72347242
14. Director-General W. *WHO Remarks at the Media Briefing on 2019-nCoV on 11 February 2020*. Geneva: World Heal Orgnatization (2020).
15. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) settings: recommendations from the REPROGRAM consortium. *Front Cardiovasc Med*. (2020) 7:112. doi: 10.3389/fcvm.2020.00112
16. Bhaskar S, Rastogi A, Menon KV, Kunheri B, Balakrishnan S, Howick J. Call for action to address equity and justice divide during COVID-19. *Front Psychiatry*. (2020) 11:1411. doi: 10.3389/fpsyt.2020.559905
17. Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, D'Amico F, Buonocunto F, et al. Mainstream technology to support basic communication and leisure in people with neurological disorders, motor impairment and lack of speech. *Brain Inj*. (2020) 34:921–7. doi: 10.1080/02699052.2020.1763462
18. Chandrakala S. Machine learning based assistive speech technology for people with neurological disorders. In: Costin H, Schuller B, Florea A, editors. *Recent Advances in Intelligent Assistive Technologies: Paradigms and Applications*. Cham, New York, NY: Springer (2020). p. 143–63. doi: 10.1007/978-3-030-30817-9_6
19. Mishra R, Banerjea AC. Neurological damage by coronaviruses: a catastrophe in the queue! *Front Immunol*. (2020) 11:2204. doi: 10.3389/fimmu.2020.565521
20. Bertelli MO, Rossi M, Varrucciu N, Bianco A, Scuticchio D, Del Furia C, et al. Relationship between psychiatric disorders and adaptive functioning in adults with intellectual disabilities. *Adv Ment Heal Intellect Disabil*. (2016) 10:92–101. doi: 10.1108/AMHID-08-2015-0038
21. Papais Alvarenga RM, de Araújo e Araújo ACR, Nascimento ACB, de Araujo NEC, Meneguette NS, Neri VC, et al. Is Asian type MS an MS phenotype, an NMO spectrum disorder, or a MOG-IgG related disease? *Mult Scler Relat Disord*. (2020) 42:102082. doi: 10.1016/j.msard.2020.102082
22. Troncoso-Escudero P, Sepulveda D, Pérez-Arancibia R, Parra AV, Arcos J, Grunenwald F, et al. On the right track to treat movement disorders: promising therapeutic approaches for Parkinson's and Huntington's disease. *Front Aging Neurosci*. (2020) 12:284. doi: 10.3389/fnagi.2020.571185
23. Caldwell DJ, Ojemann JG, Rao RPN. Direct electrical stimulation in electrocorticographic brain-computer interfaces: enabling technologies for input to cortex. *Front Neurosci*. (2019) 13:804. doi: 10.3389/fnins.2019.00804
24. Mayo CD, Miksche K, Attwell-Pope K, Gawryluk JR. The relationship between physical activity and symptoms of fatigue, mood, and perceived cognitive impairment in adults with multiple sclerosis. *J Clin Exp Neuropsychol*. (2019) 41:715–22. doi: 10.1080/13803395.2019.1614535
25. Dekhtyar S, Marseglia A, Xu W, Darin-Mattsson A, Wang HX, Fratiglioni L. Genetic risk of dementia mitigated by cognitive reserve: a cohort study. *Ann Neurol*. (2019) 86:68–78. doi: 10.1002/ana.25501

26. Koumakis L, Chatzaki C, Kazantzaki E, Maniadi E, Tsiknakis M. Dementia care frameworks and assistive technologies for their implementation: a review. *IEEE Rev Biomed Eng*. (2019) 12:4–18. doi: 10.1109/RBME.2019.2892614
27. Stamford JA, Schmidt PN, Friedl KE. What engineering technology could do for quality of life in Parkinson's disease: a review of current needs and opportunities. *IEEE J Biomed Heal Informat*. (2015) 19:1862–72. doi: 10.1109/JBHI.2015.2464354
28. Jamieson M, Cullen B, McGee-Lennon M, Brewster S, Evans JJ. The efficacy of cognitive prosthetic technology for people with memory impairments: a systematic review and meta-analysis. *Neuropsychol Rehabil*. (2014) 24:419–44. doi: 10.1080/09602011.2013.825632
29. Brandt Å, Jensen MP, Søberg MS, Andersen SD, Sund T. Information and communication technology-based assistive technology to compensate for impaired cognition in everyday life: a systematic review. *Disabil Rehabil Assist Technol*. (2020) 15:810–24. doi: 10.1080/17483107.2020.1765032
30. Clasby B, Hughes N, Catroppa C, Morrison E. Community-based interventions for adolescents following traumatic brain injury: a systematic review. *NeuroRehabilitation*. (2018) 42:345–63. doi: 10.3233/NRE-172385
31. Charters E, Gillett L, Simpson GK. Efficacy of electronic portable assistive devices for people with acquired brain injury: a systematic review. *Neuropsychol Rehabil*. (2015) 25:82–121. doi: 10.1080/09602011.2014.942672
32. Des Roches CA, Kiran S. Technology-based rehabilitation to improve communication after acquired brain injury. *Front Neurosci*. (2017) 11:382. doi: 10.3389/fnins.2017.00382
33. Bhaskar S, Bradley S, Israeli-Korn S, Menon B, Chattu VK, Thomas P, et al. Chronic neurology in COVID-19 era: clinical considerations and recommendations from the REPROGRAM Consortium. *Front Neurol*. (2020) 11:664. doi: 10.3389/fneur.2020.00664
34. Bloem BR, Dorsey ER, Okun MS. The coronavirus disease 2019 crisis as catalyst for telemedicine for chronic neurological disorders. *JAMA Neurol*. (2020) 77:927–8. doi: 10.1001/jamaneurol.2020.1452
35. Chen PM, Hemmen TM. Evolving healthcare delivery in neurology during the coronavirus disease 2019 (COVID-19) pandemic. *Front Neurol*. (2020) 11:578. doi: 10.3389/fneur.2020.00578
36. Platz T, Sandrini G. Specialty grand challenge for neurorehabilitation research. *Front Neurol*. (2020) 11:349. doi: 10.3389/fneur.2020.00349
37. Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, Alberti G, Perilli V, et al. An upgraded smartphone-based program for leisure and communication of people with intellectual and other disabilities. *Front Public Health*. (2018) 6:234. doi: 10.3389/fpubh.2018.00234
38. Comer JS, Furr JM, Cooper-Vince C, Madigan RJ, Chow C, Chan PT, et al. Rationale and considerations for the internet-based delivery of parent–child interaction therapy. *Cogn Behav Pract*. (2015) 22:302–16. doi: 10.1016/j.cbpra.2014.07.003
39. Lancioni GE, O'Reilly MF, Singh NN, Sigafoos J, Buonocunto F, Sacco V, et al. Technology-aided leisure and communication opportunities for two post-coma persons emerged from a minimally conscious state and affected by multiple disabilities. *Res Dev Disabil*. (2013) 34:809–16. doi: 10.1016/j.ridd.2012.10.008
40. Lancioni GE, O'Reilly MF, Singh NN, Sigafoos J, Green VA, Oliva D, et al. Two women with multiple disabilities communicate with distant partners via a special text messaging system. *Res Dev Disabil*. (2013) 34:397–403. doi: 10.1016/j.ridd.2012.08.024
41. Isernia S, Pagliari C, Jonsdottir J, Castiglioni C, Gindri P, Gramigna C, et al. Efficiency and patient-reported outcome measures from clinic to home: the human empowerment aging and disability program for digital-health rehabilitation. *Front Neurol*. (2019) 10:1206. doi: 10.3389/fneur.2019.01206
42. Baker S, Kelly RM, Waycott J, Carrasco R, Hoang T, Batchelor F, et al. Interrogating social virtual reality as a communication medium for older adults. *Proc ACM Hum Comput Interact*. (2019) 3:1–24. doi: 10.1145/3359251
43. Slater M, Neyret S, Johnston T, Iruretagoyena G, de la Campa Crespo MÁ, Alabèrnia-Segura M, et al. An experimental study of a virtual reality counselling paradigm using embodied self-dialogue. *Sci Rep*. (2019) 9:10903 doi: 10.1038/s41598-019-46877-3
44. Osimo SA, Pizarro R, Spanlang B, Slater M. Conversations between self and self as Sigmund Freud—A virtual body ownership paradigm for self counselling. *Sci Rep*. (2015) 5:13899. doi: 10.1038/srep13899
45. Perez-Marcos D, Solazzi M, Steptoe W, Oyekoya O, Frisoli A, Weyrich T, et al. A fully immersive set-up for remote interaction and neurorehabilitation based on virtual body ownership. *Front Neurol*. (2012) 3:110. doi: 10.3389/fneur.2012.00110
46. Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, Alberti G, Chiariello V, et al. Extended smartphone-aided program to sustain daily activities, communication and leisure in individuals with intellectual and sensory-motor disabilities. *Res Dev Disabil*. (2020) 105:103722. doi: 10.1016/j.ridd.2020.103722
47. Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, Alberti G, Perilli V, et al. A tablet-based program to enable people with intellectual and other disabilities to access leisure activities and video calls. *Disabil Rehabil Assist Technol*. (2020) 15:14–20. doi: 10.1080/17483107.2018.1508515
48. Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, Boccasini A, Perilli V, et al. Persons with multiple disabilities manage positive leisure and communication engagement through a technology-aided program. *Int J Dev Disabil*. (2017) 63:148–57. doi: 10.1080/20473869.2016.1187462
49. Lancioni GE, Singh NN, O'Reilly MF, Sigafoos J, Alberti G, Perilli V, et al. Technology-aided options for helping persons with multiple disabilities engage in communication behavior. *Life Span Disabil*. (2017) 20:7–26.
50. Lancioni GE, O'Reilly MF, Singh NN, Sigafoos J, Buonocunto F, Sacco V, et al. Communication opportunities via special messaging technology for two post-coma persons with multiple disabilities. *Res Dev Disabil*. (2011) 32:1703–8. doi: 10.1016/j.ridd.2011.02.025
51. Lancioni G, O'Reilly M, Singh N, Buonocunto F, Sacco V, Colonna F, et al. Technology-assisted messaging opportunities for two persons emerged from a minimally conscious state and showing extensive motor disabilities. *Dev Neurorehabil*. (2011) 14:8–14. doi: 10.3109/17518423.2010.519760
52. Orsini A, Corsi M, Santangelo A, Riva A, Peroni D, Foiadelli T, et al. Challenges and management of neurological and psychiatric manifestations in SARS-CoV-2 (COVID-19) patients. *Neurol Sci*. (2020) 41:2353–66. doi: 10.1007/s10072-020-04544-w
53. Caligari M, Godi M, Giardini M, Colombo R. Development of a new high sensitivity mechanical switch for augmentative and alternative communication access in people with amyotrophic lateral sclerosis. *J Neuroeng Rehabil*. (2019) 16:1–3. doi: 10.1186/s12984-019-0626-5
54. Field MJ, Grigsby J. Telemedicine and remote patient monitoring. *J Am Med Assoc*. (2002) 288:423–5. doi: 10.1001/jama.288.4.423
55. Hampson N, King L, Eriksson LM, Smee H. The effects of relaxation training on depression and anxiety in people living with long-term neurological conditions. *Disabil Rehabil*. (2020) 42:2100–5. doi: 10.1080/09638288.2018.1554009
56. Amanzio M, Bartoli M, Cipriani GE, Palermo S. Executive dysfunction and reduced self-awareness in patients with neurological disorders. A mini-review. *Front Psychol*. (2020) 11:1697. doi: 10.3389/fpsyg.2020.01697
57. Szemere E, Jokeit H. Quality of life is social-towards an improvement of social abilities in patients with epilepsy. *Seizure*. (2015) 26:12–21. doi: 10.1016/j.seizure.2014.12.008
58. Felgoise SH, Zaccheo V, Duff J, Simmons Z. Verbal communication impacts quality of life in patients with amyotrophic lateral sclerosis. *Amyotroph Lateral Scler Front Degener*. (2016) 17:179–83. doi: 10.3109/21678421.2015.1125499
59. Reverté-Villarroya S, Dávalos A, Font-Mayolas S, Berenguer-Poblet M, Sauras-Colón E, López-Pablo C, et al. Coping strategies, quality of life, and neurological outcome in patients treated with mechanical thrombectomy after an acute ischemic stroke. *Int J Environ Res Public Health*. (2020) 17:6014. doi: 10.3390/ijerph17176014
60. Oleen-Burkey MK, Castelli-Haley J, Lage MJ, Johnson KP. Burden of a multiple sclerosis relapse: the patients perspective. *Patient*. (2012) 5:57–69. doi: 10.2165/11592160-000000000-00000
61. Ellul MA, Benjamin L, Singh B, Lant S, Michael BD, Easton A, et al. Neurological associations of COVID-19. *Lancet Neurol*. (2020) 19:767–83. doi: 10.1016/S1474-4422(20)30221-0
62. Srivastav AK, Samuel AJ. E-rehabilitation: one solution for patients with Parkinson's disease in COVID-19 era. *Parkinsonism Relat Disord*. (2020) 75:128–9. doi: 10.1016/j.parkreldis.2020.05.021
63. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the new outpatient clinic gone digital: position paper from the pandemic health system REsilience PROGRAM (REPROGRAM)

international consortium (part 2). *Front Public Health*. (2020) 8:410. doi: 10.3389/fpubh.2020.00410
64. Hosseiniravandi M, Kahlaee AH, Karim H, Ghamkhar L, Safdari R. Home-based telerehabilitation software systems for remote supervising: a systematic review. *Int J Technol Assess Health Care*. (2020) 36:113–25. doi: 10.1017/S0266462320000021
65. Matamala-Gomez M, Maisto M, Montana JI, Mavrodiev PA, Baglio F, Rossetto F, et al. The role of engagement in teleneurorehabilitation: a systematic review. *Front Neurol*. (2020) 11:354. doi: 10.3389/fneur.2020.00354
66. Matamala-Gomez M, De Icco R, Avenali M, Balsamo F. Multisensory integration techniques in neurorehabilitation: the use of virtual reality as a rehabilitation tool. *Confin Cephalalgica*. (2018) 28:81–5.
67. Kay A. Computer software. *Sci Am*. (1984) 251:52–9. doi: 10.1038/scientificamerican0984-52
68. Biocca F, Delaney B. Immersive virtual reality technology. *Commun Age virtual Real*. (1995) 15:1–68.
69. Biocca F, Levy M, editors. Virtual reality as a communication system. In: *Communication in the Age of Virtual Reality*. New York, NY: Routledge (1995). p. 416.
70. Riva G. Virtual reality as communication tool: a sociocognitive analysis. *Presence Teleoper Virtual Environ*. (1999) 8:462–8. doi: 10.1162/105474699566341
71. Brooks FP. What's real about virtual reality? *IEEE Comput Graph Appl*. (1999) 19:16–27. doi: 10.1109/38.799723
72. Slater M, Wilbur S. A framework for immersive virtual environments (FIVE): speculations on the role of presence in virtual environments. *Presence Teleoper Virtual Environ*. (1997) 6:603–16. doi: 10.1162/pres.1997.6.6.603
73. D'Cunha NM, Nguyen D, Naumovski N, McKune AJ, Kellett J, Georgousopoulou EN, et al. A mini-review of virtual reality-based interventions to promote well-being for people living with dementia and mild cognitive impairment. *Gerontology*. (2019) 65:430–40. doi: 10.1159/000500040
74. Bourrelier J, Ryard J, Dion M, Merienne F, Manckoundia P, Mourey F. Use of a virtual environment to engage motor and postural abilities in elderly subjects with and without mild cognitive impairment (MAAMI Project). *Irbm*. (2016) 37:75–80. doi: 10.1016/j.irbm.2016.02.007
75. Riva G, Mantovani F. Being there: understanding the feeling of presence in a synthetic environment and its potential for clinical change. In: Eichenberg C, editor. *Virtual Reality in Psychological, Medical and Pedagogical Applications*. London: Intechopen (2012). p. 3–34. doi: 10.5772/46411
76. Schroeder R. *Possible Worlds: The Social Dynamic of Virtual Reality Technology*. Boulden: Westview Press, Inc (1996).
77. Bhaskar S, Bradley S, Sakhamuri S, Moguilner S, Chattu VK, Pandya S, et al. Designing futuristic telemedicine using artificial intelligence and robotics in the COVID-19 era. *Front Public Health*. (2020) 8:708. doi: 10.3389/fpubh.2020.556789
78. Riva G, Davide F, IJsselsteijn WA (editors). Being there: the experience of presence in mediated environments. In: *Being There: Concepts, Effects and Measurement of User Presence in Synthetic Environments*. Amsterdam: IOS Press (2003). p. 5.
79. Mantovani G, Riva G. "Real" presence: how different ontologies generate different criteria for presence, telepresence, and virtual presence. *Presence Teleoper Virtual Environ*. (1999) 8:540–50. doi: 10.1162/1054746995 66459
80. Riva G. Design of clinically oriented virtual environments: a communicational approach. *Cyberpsychol Behav*. (2000) 3:351–7. doi: 10.1089/10949310050078797
81. Riva G. Virtual reality and telepresence. *Science*. (2007) 318:1240–2. doi: 10.1126/science.318.5854.1240d
82. Lenggenhager B, Tadi T, Metzinger T, Blanke O. Video ergo sum: manipulating bodily self-consciousness. *Science*. (2007) 317:1096–9. doi: 10.1126/science.1143439
83. Petkova VI, Ehrsson HH. If i were you: perceptual illusion of body swapping. *PLoS ONE*. (2008) 3:e3832. doi: 10.1371/journal.pone.0003832
84. Slater M, Perez-Marcos D, Ehrsson HH, Sanchez-Vives M V. Inducing illusory ownership of a virtual body. *Front Neurosci*. (2009) 3:29. doi: 10.3389/neuro.01.029.2009
85. Tuena C, Pedroli E, Trimarchi PD, Gallucci A, Chiappini M, Goulene K, et al. Usability issues of clinical and research applications of virtual reality in older people: a systematic review. *Front Hum Neurosci*. (2020) 14:93. doi: 10.3389/fnhum.2020.00093
86. Badler NI, Erignac CA, Liu Y. Virtual humans for validating maintenance procedures. *Commun ACM*. (2002) 45:56–63. doi: 10.1145/514236.514264
87. Matamala-Gomez M, Malighetti C, Cipresso P, Pedroli E, Realdon O, Mantovani F, et al. Changing body representation through full body ownership illusions might foster motor rehabilitation outcome in patients with stroke. *Front Psychol*. (2020) 11:1962. doi: 10.3389/fpsyg.2020.01962
88. Matamala Gómez M. *The Use of Immersive Virtual Reality in Neurorehabilitation and its Impact in Neuroplasticity*. (Doctoral dissertation), Barcelona: Universitat de Barcelona (2017).
89. Matamala-Gomez M, Donegan T, Bottiroli S, Sandrini G, Sanchez-Vives M V., Tassorelli C. Immersive virtual reality and virtual embodiment for pain relief. *Front Hum Neurosci*. (2019) 13:279. doi: 10.3389/fnhum.2019.00279
90. Moustafa F. *Social VR-an Investigation into the Affective Triggers of Virtual Reality*. UCL Interaction Center, University College London, HCI-E MSc Final Project Report (2017).
91. Lugrin JL, Latt J, Latoschik ME. Avatar anthropomorphism and illusion of body ownership in VR. In: *2015 IEEE Virtual Reality (VR)*. Arles: IEEE (2015). p. 229–30. doi: 10.1109/VR.2015.7223379
92. Orts-Escolano S, Rhemann C, Fanello S, Chang W, Kowdle A, Degtyarev Y, et al. Holoportation: virtual 3d teleportation in real-time. In: *Proceedings of the 29th Annual Symposium on User Interface Software and Technology*. New York, NY (2016). p. 741–54. doi: 10.1145/2984511.2984517
93. Scuteri D, Matamala-Gomez M, Bottiroli S, Corasaniti MT, De Icco R, Bagetta G, et al. Pain assessment and treatment in dementia at the time of coronavirus disease covid-19. *Front Neurol*. (2020) 11:890. doi: 10.3389/fneur.2020.00890
94. Salawu A, Green A, Crooks MG, Brixey N, Ross DH, Sivan M. A proposal for multidisciplinary tele-rehabilitation in the assessment and rehabilitation of COVID-19 survivors. *Int J Environ Res Public Health*. (2020) 17:4890. doi: 10.3390/ijerph17134890
95. Simpson R, Robinson L. Rehabilitation after critical illness in people with COVID-19 infection. *Am J Phys Med Rehabil*. (2020) 99:470–4. doi: 10.1097/PHM.0000000000001480
96. Lopez M, Bell K, Annaswamy T, Juengst S, Ifejika N. COVID-19 guide for the rehabilitation clinician: a review of nonpulmonary manifestations and complications. *Am J Phys Med Rehabil*. (2020) 99:669–76. doi: 10.1097/PHM.0000000000001479
97. Curci C, Pisano F, Bonacci E, Camozzi DM, Ceravolo C, Bergonzi R, et al. Early rehabilitation in post-acute COVID-19 patients: data from an Italian COVID-19 rehabilitation unit and proposal of a treatment protocol. *Eur J Phys Rehabil Med*. (2020) 56:633–41. doi: 10.23736/S1973-9087.20. 06339-X
98. Sivan M, Halpin S, Hollingworth L, Snook N, Hickman K, Clifton IJ. Development of an integrated rehabilitation pathway for individuals recovering from COVID-19 in the community. *J Rehabil Med*. (2020) 52:jrm00089. doi: 10.2340/16501977-2727
99. Matamala-Gomez M, De Icco R, Sandrini G. Telemedicina e realtà virtuale ai tempi della pandemia da Covid-19. *Confinia Cephalalg Neurol*. (2020) 30:79–83.
100. Negrini S, Kiekens C, Bernetti A, Capecci M, Ceravolo MG, Lavezzi S, et al. Telemedicine from research to practice during the pandemic "instant paper from the field" on rehabilitation answers to the COVID-19 emergency. *Eur J Phys Rehabil Med*. (2020) 56:327–30. doi: 10.23736/S1973-9087.20. 06331-5
101. Leocani L, Diserens K, Moccia M, Caltagirone C, Neurorehabilitation scientific panel of the european academy of neurology-EAN. Disability through COVID-19 pandemic: neurorehabilitation cannot wait. *Eur J Neurol*. (2020) 27:e50–1. doi: 10.1111/ene.14320
102. De Biase S, Cook L, Skelton DA, Witham M, Ten Hove R. The COVID-19 rehabilitation pandemic. *Age Ageing*. (2020) 49:696–700. doi: 10.1093/ageing/afaa118
103. Chirra M, Marsili L, Wattley L, Sokol LL, Keeling E, Maule S, et al. Telemedicine in neurological disorders: opportunities and challenges. *Telemed e-Health*. (2019) 25:541–50. doi: 10.1089/tmj.2018.0101

104. Montana JI, Gomez MM, Maisto M, Mavrodiev PA, Cavalera CM, Diana B, et al. The benefits of emotion regulation interventions in virtual reality for the improvement of wellbeing in adults and older adults: a systematic review. *J Clin Med*. (2020) 9:500. doi: 10.3390/jcm9020500
105. Tuena C, Semonella M, Fernández-Álvarez J, Colombo D, Cipresso P. Predictive precision medicine: towards the computational challenge. In: Pravettoni G, Triberti S, editors. *P5 eHealth: An Agenda for the Health Technologies of the Future*. Cham: Springer (2020). p. 71–86. doi: 10.1007/978-3-030-27994-3_5
106. Soares WB, Silvestre IT, Lima AM de O, de Almondes KM. The influence of telemedicine care on the management of behavioral and psychological symptoms in dementia (BPSD) risk factors induced or exacerbated during the COVID-19 pandemic. *Front Psychiatry*. (2020) 11:965. doi: 10.3389/fpsyt.2020.577629
107. Mantovani E, Zucchella C, Bottiroli S, Federico A, Giugno R, Sandrini G, et al. Telemedicine and virtual reality for cognitive rehabilitation: a roadmap for the COVID-19 pandemic. *Front Neurol*. (2020) 11:926. doi: 10.3389/fneur.2020.00926
108. Maggio MG, De Luca R, Manuli A, Calabrò RS. The five 'W' of cognitive telerehabilitation in the Covid-19 era. *Expert Rev Med Devices*. (2020) 17:473–5. doi: 10.1080/17434440.2020.1776607
109. Rajavenkatanarayanan A, Kanal V, Tsiakas K, Calderon D, Papakostas M, Abujelala M, et al. A survey of assistive technologies for assessment and rehabilitation of motor impairments in multiple sclerosis. *Multimodal Technol Interact*. (2019) 3:6. doi: 10.3390/mti3010006
110. Connors K, Mahony L, Morgan P. Variation in assistive technology use in motor neuron disease according to clinical phenotypes and ALS functional rating scale-revised score: a prospective observational study. *NeuroRehabilitation*. (2019) 44:303–13. doi: 10.3233/NRE-182511
111. Stasolla F, Damiani R, Perilli V, D'Amico F, Caffò AO, Stella A, et al. Computer and microswitch-based programs to improve academic activities by six children with cerebral palsy. *Res Dev Disabil*. (2015) 45–6:1–13. doi: 10.1016/j.ridd.2015.07.005
112. Pinto S, Quintarelli S, Silani V. New technologies and amyotrophic lateral sclerosis–which step forward rushed by the COVID-19 pandemic? *J Neurol Sci*. (2020) 418:117081. doi: 10.1016/j.jns.2020.117081
113. Fried-Oken M, Mooney A, Peters B. Supporting communication for patients with neurodegenerative disease. *NeuroRehabilitation*. (2015) 37:69–87. doi: 10.3233/NRE-151241
114. Stasolla F, Caffò AO, Perilli V, Boccasini A, Damiani R, D'Amico F. Assistive technology for promoting adaptive skills of children with cerebral palsy: ten cases evaluation. *Disabil Rehabil Assist Technol*. (2019) 14:489–502. doi: 10.1080/17483107.2018.1467972
115. Di Carlo F, Sociali A, Picutti E, Pettorruso M, Vellante F, Verrastro V, et al. Telepsychiatry and other cutting-edge technologies in COVID-19 pandemic: bridging the distance in mental health assistance. *Int J Clin Pract*. (2020) 75:e13716. doi: 10.1111/ijcp.13716
116. Bernini S, Panzarasa S, Barbieri M, Sinforiani E, Quaglini S, Tassorelli C, et al. A double-blind randomized controlled trial of the efficacy of cognitive training delivered using two different methods in mild cognitive impairment in Parkinson's disease: preliminary report of benefits associated with the use of a computerized tool. *Aging Clin Exp Res*. (2020) 8:1–9. doi: 10.1007/s40520-020-01665-2
117. Lancioni GE, O'Reilly MF, Singh NN, Sigafoos J, Grumo G, Pinto K, et al. Assessing the impact and social perception of self-regulated music stimulation with patients with Alzheimer's disease. *Res Dev Disabil*. (2013) 34:139–46. doi: 10.1016/j.ridd.2012.07.026

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