International Journal of Infectious Diseases 117 (2022) 93–96

Contents lists available at ScienceDirect

International Journal of Infectious Diseases

journal homepage: www.elsevier.com/locate/ijid

Review

Virtual Infection Prevention and Control in Low- and Middle-Income Countries

Tristan Jones[1,*], Kalisvar Marimuthu[2], Gonzalo Bearman[1]

[1] Division of Infectious Diseases, Virginia Commonwealth University, Richmond, Virginia
[2] Department of Infectious Diseases, Tan Tock Seng Hospital; HAI surveillance unit, National Centre for Infectious Diseases; Infection Prevention and Control Office, Woodlands Health Campus; Yong Loo Lin School of Medicine, National University of Singapore

ARTICLE INFO

Article history:
Received 15 December 2021
Revised 26 January 2022
Accepted 28 January 2022

ABSTRACT

COVID-19 brought new challenges and opportunities for infection prevention and control. Virtual infection prevention and control (VIPC), although nascent, is rapidly becoming a viable and necessary strategy for combatting the COVID-19 pandemic. Benefits of VIPC include extending the impact of globally scarce infectious disease providers and public health practitioners, allowing coordination between disparate professionals to more effectively combat infectious disease, and increasing access to and quality of healthcare. Although mainly applied in developed countries, VIPC may play its greatest role in low- and middle-income countries (LMICs) with fewer healthcare resources. We conducted a brief literature search of VIPC in LMICs and found that many studies describe solutions in developed countries or describe planned or theoretical solutions. Few studies describe actual VIPC implementation in LMICs, except for China. Literature from related fields, for example, virtual critical care, and from developed countries is more robust and provides a roadmap for future research on VIPC in LMICs. Further research into strategies and outcomes related to VIPC in LMICs is necessary.

1. Introduction

The COVID-19 pandemic brought unprecedented challenges and opportunities to infection prevention and control (IPC) efforts globally. It has spurred healthcare workers and healthcare systems to implement new technologies and strategies for IPC. Virtual infection prevention and control (VIPC) refers to the technologies and strategies separated geographically or temporally from the point of medical care to control the spread of contagious diseases. Although a new field, VIPC has been rapidly employed in a variety of contexts throughout the pandemic as healthcare providers adapted to and innovated in the changing IPC landscape. Many of the new techniques were implemented in developed nations with well-funded healthcare systems, advanced technological infrastructure, and individual-level access to technology and equipment. Low- and middle-income countries (LMICs) have also experimented with VIPC during the pandemic. VIPC may have a greater impact in these nations because they have less well-developed healthcare systems and fewer resources to devote to IPC. As the urgency and severity of this pandemic wane, VIPC will remain a viable tool for such countries to advance IPC.

2. Benefits of virtual infection prevention and control

VIPC provides multiple benefits, particularly in resource-limited settings. First, the COVID-19 pandemic demonstrated the scarcity of infectious disease doctors, epidemiologists, and public health officials globally (Walensky et al., 2020; Williams et al., 2020). Professionals from a wide swathe of public health and infectious disease fields were reallocated to combat COVID-19, further exacerbating shortages in IPC for other diseases. This is a known problem in developed nations such as the United States, and likely worse in LMICs. Several reasons for this include reimbursement regimes that devalue infectious disease and public health work, governmental and charitable disinterest in funding a largely preventative field with a long investment horizon, and for-profit health systems that largely fail to reward preventative strategies such as vaccines. Often these issues are exacerbated for LMICs as resources are more limited and healthcare systems tend to be more privately funded than in developed countries (OECD, 2021).

Second, VIPC is important because it allows fast and geographically remote communication. Many LMICs have rapidly gained ac-

* Corresponding author.
E-mail address: Tristan.Jones@vcuhealth.org (T. Jones).

https://doi.org/10.1016/j.ijid.2022.01.065
1201-9712/

cess to digital communication technologies from instant messaging to smartphones that allow for easy communication. As pandemics are by definition global, the response needs to be global as well. International networks of epidemiologists and infectious disease providers are much more effective than siloed teams. The pandemic likely would have been much worse had not professionals in the first-affected areas rapidly disseminated information on preventing the spread of SARS-CoV-2 both within the healthcare systems and in public settings. For example, the determination that the virus could spread by way of airborne particles resulted in rapid uptake of mask-wearing globally, and the early publication of the genetic sequence allowed rapid rollout of test kits. Moving beyond the immediate pandemic, VIPC will remain important as global issues such as antimicrobial resistance worsen and require effective, decentralized teams of providers around the globe.

Third, VIPC is easily integrated with telehealth, defined as “the use of telecommunications and information technology to provide access to health assessment, diagnosis, intervention, consultation, supervision and information across distance” (Keyser and Baumrucker, 2020). The same technologies and strategies are often used to communicate with patients, the public, and healthcare providers. Telehealth, in its infancy before the pandemic, has rapidly grown and expanded and will remain a fixture in healthcare systems going forward. Telehealth can provide better healthcare—increasing accessibility through virtual provider visits, and improving quality, in the case of digital applications to better diagnose illness—than traditional healthcare delivery systems. Artificial intelligence (AI) can augment and enhance some of these technologies. However, some attributes such as easier access to healthcare providers, better patient access to health information by way of the internet, and the ever-expanding volume of personal health data run the risk of overburdening already stressed healthcare systems. IPC programs already suffer from underfunding and limited resources for monitoring, data processing, outreach, and education. VIPC provides a possible solution to this problem by extending the reach or impact of infection control practitioners and allowing remote providers and technologies to relieve the local burden in LMICs.

3. Current state of virtual infection prevention and control literature

3.1. Virtual infection prevention and control in mostly developed nations

Current literature on VIPC is limited. A PubMed search in August 2020 using the Medical Subject Headings (MeSH) terms “remote consultation”, “remote sensing technology”, “telemedicine”, or “online systems” combined with “infection control” or “infection control practitioners” yielded 320 published articles, 11 of which described VIPC efforts (Table 1). Pryor et al. (2021) describe potential VIPC applications in the United States (US), including using AI, in this case, machine learning, to better characterize emerging epidemiologic threats. The authors advocate for smarter use of the vast data contained in electronic medical records to better surveil for hospital-acquired infections (HAIs) (Pryor et al., 2021). A referenced example, the Duke Infection Control Outreach Network, demonstrates the efficacy of a formalized VIPC network in the US (Anderson et al., 2011). The program provides community hospitals with access to remote hospital epidemiologists and infection preventionists at an academic institution, with associated monthly visits, data analysis and feedback, focused strategies to reduce infection rates, outbreak investigation, and educational programs. By using these combined virtual and non-virtual methods the program reduced rates of HAIs by approximately 50% in participating community hospitals over the 7 years studied.

Kalhori et al. (2021) conducted a search for digital solutions for combatting COVID-19 in mostly developed nations, including only the US, China, and countries in Western Europe. They describe 6 categories of methods: telemedicine services, digital learning packages, location-based tracking, mobile applications, clinical decision support systems, and social media. Although some of these rely on digital infrastructure, all could potentially be implemented in LMICs at a reasonable cost. Notably, 11 of the 32 mentioned studies are from China, though most are not related specifically to VIPC but rather digital solutions more broadly. Several studies describe a VIPC method of using smartphone applications to track exposures, although none have quantitative results of outcomes (Kamel Boulos and Geraghty, 2020; Pan et al., 2020; Pan, 2020). One such study specifically described using AI to better characterize disease transmission patterns to help predict and prevent outbreaks at the regional or even hospital level (Gong et al., 2020). It may be notable that China has been largely successful in pandemic-mitigation efforts, although it remains unknown whether this is related to VIPC and the other digital solutions mentioned in this paper or to other factors. Importantly, Kalhori et al. reference only studies of solutions that have been implemented during this pandemic rather than theoretical or planned solutions.

Scott et al. (2020) describe several solutions related to VIPC concerning critical care medicine. They outline a national strategy for extending the impact of the limited number of critical care providers in the US, a roadmap that could be adapted for infectious disease providers and VIPC. One notable piece of the strategy is telementoring, where an expert physician (e.g. an intensivist) guides a geographically separated group of front-line, less-specialized healthcare workers, for instance, non-intensivist physicians or advanced practice providers. Bundled with other remote technologies and tools such as remote monitoring and AI, a small group of providers can have a disproportionate impact. Ramnath et al. (2021) describe an actual cross-border telemedicine intensive care unit between the US and Mexico.

3.2. Feasibility studies, planned studies, and theoretical applications

Other VIPC strategies described in the literature vary from randomized controlled trials to compiled expert recommendations to perspectives on the implementation of possible future technologies. The feasibility of using remote monitoring of patients with tracking applications, including location-enabled applications with daily symptom checkers, has been validated in some developed nations (Varsavsky et al., 2020). A planned study to use mobile phone messaging to increase hand hygiene compliance in Uganda is an example of VIPC in an LMIC (Mugambe et al., 2021). This study had not yet been conducted at the time of publication. Another study from sub-Saharan Africa describes how subspecialty care, in this case, pediatric cardiology, can use teleconsults and teleradiology to continue providing services (Sokunbi et al., 2020). A real-world randomized controlled trial of a web-based training module about personal protective equipment from Switzerland could be implemented in LMICs (Suppan et al., 2020). Theoretical VIPC applications described in the literature include applying AI to radiology images to detect infectious diseases, using robots to disinfect facilities, and using telecommunications to conduct clinical trials (Alwashmi, 2020; Brezing et al., 2020; Khan et al., 2020).

3.3. Summary of virtual infection prevention and control literature

The COVID-19 pandemic sparked an explosion of telemedicine and early steps at VIPC across the globe. The literature on VIPC has been limited, however, to mostly developed nations, and much of it describes theoretical or planned interventions. The main study that describes implemented solutions is limited to developed nations

Table 1
State of current literature regarding virtual infection prevention and control (VIPC).

Paper	Summary of virtual infection prevention and control topic	Results (if applicable)
Alwashmi, 2020	Commentary on technological advances such as thermal imaging technology and deep learning of radiology images applied to COVID-19	Commentary, no results
Brezing et al., 2020	Commentary on how virtual clinical trials may continue during a pandemic by using digital methods for recruitment, screening, informed consent, other study procedures, and internal lab operations	Commentary, no results
Kalhori et al., 2021	Review of digital health solutions for combatting COVID-19, including clinical decision support systems and social media tracking that can be used for pandemic surveillance	Most digital health solutions have been applied in developed countries, however, China has applied multiple web- and mobile-based tools to effectively combat the pandemic
Khan et al., 2020	Commentary on how robots, which already exist in hospitals worldwide, can clean and disinfect facilities	Commentary, no results
Mugambe et al., 2021	Study methodology for an ongoing study using mobile phone messaging interventions to increase hand hygiene compliance amongst healthcare workers in Uganda	Planned study, no results
Pryor et al., 2021	Theoretical application of machine learning and electronic medical record data processing to remotely surveil for hospital-acquired infections	Commentary, no results
Ramnath et al., 2021	Real-world description of a cross-border "Tele-ICU" that provides on-demand individual patient consultations by US intensive care unit specialists to hospitals in Mexico	An effective cross-border telemedicine program was established to extend the reach of United States-based intensivists
Scott et al., 2020	Description of advanced technologies that are possibly helpful with VIPC related to COVID-19: telemedicine and mobile care, tiered telementoring, telecritical care, robotics, and artificial intelligence for monitoring	Commentary, no results
Sokunbi et al., 2020	Compiled recommendations for keeping specialized cardiology care, including surgery, available to pediatric patients in sub-Saharan Africa during the pandemic, including teleconsultations from experts in developed nations	One specialty hospital in Nigeria continued providing necessary care despite the pandemic
Suppan et al., 2020	Real-world randomized-controlled trial of a web-based training module for proper personal protective equipment use in Switzerland	No significant difference in knowledge of personal protective equipment was found between traditional guideline-based training and a gamified e-learning platform
Varsavsky et al., 2020	Real-world validation of a downloadable tracking app with daily questionnaire to study community spread of COVID-19 in the United Kingdom	A self-reported symptom checker app had similar detection of SARS-CoV-2 spread as traditional national community surveys

Abbreviations: COVID-19 = coronavirus disease 2019; VIPC = virtual infection prevention and control.

and China (Kalhori et al., 2021). The lack of published literature on VIPC in LMICs does not necessarily imply that it is not being studied or implemented in these countries. Further research in this area is warranted.

4. Conclusions and future directions

VIPC will be an important strategy going forward for ending the COVID-19 pandemic and addressing whatever pandemic comes next. VIPC extends the impact of limited providers and healthcare resources using technology and infrastructure that largely already exists around the globe. It may be especially important in LMICs with less health system funding and fewer providers. The existing literature describes some implemented solutions in developed countries plus theoretical applications. Very limited published literature exists on applications of VIPC in LMICs, with the exception of China. Given the importance of finding far-reaching and cost-effective solutions for combatting COVID-19 and other infectious diseases, VIPC research in LMICs will be an important area of focus in the years to come. Possible future directions of research include experiments with AI to more rapidly track and diagnose infectious disease, new strategies to leverage geographically remote expertise (e.g. infectious disease experts in other countries), and the use of remote monitoring and data analysis to monitor individual patients as well as community health. These future studies should aim to quantify the impact of VIPC on managing specific problems, for example, control of antimicrobial resistance clusters, and the cost-effectiveness of such interventions compared with the existing standard of care of IPC. Some of the literature referenced in this paper describes planned VIPC studies, and it is likely that many more VIPC implementation studies are underway globally. Such studies on VIPC implementation and related outcomes are needed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding Source Statement

There was no financial support given for the research or preparation of this article.

Ethical Approval Statement

This article complied with all ethical research standards and was exempt from institutional review board approval.

References

Alwashmi MF. The Use of Digital Health in the Detection and Management of COVID-19. Int J Environ Res Public Health 2020;17:E2906. doi:10.3390/ijerph17082906.

Anderson DJ, Miller BA, Chen LF, Adcock LH, Cook E, Cromer AL, et al. The network approach for prevention of healthcare-associated infections: long-term effect of participation in the Duke Infection Control Outreach Network. Infect Control Hosp Epidemiol 2011;32:315–22. doi:10.1086/658940.

Brezing CA, Luo SX, Mariani JJ, Levin FR. Digital Clinical Trials for Substance Use Disorders in the Age of Covid-19. J Addict Med 2020;14:e297–302. doi:10.1097/ADM.0000000000000733.

Gong M, Liu L, Sun X, Yang Y, Wang S, Zhu H. Cloud-Based System for Effective Surveillance and Control of COVID-19: Useful Experiences From Hubei. China. J Med Internet Res 2020;22:e18948. doi:10.2196/18948.

Kalhori SRN, Bahaadinbeigy K, Deldar K, Gholamzadeh M, Hajesmaeel-Gohari S, Ayyoubzadeh SM, et al. Digital Health Solutions to Control the COVID-19 Pandemic in Countries With High Disease Prevalence: Literature Review. J Med Internet Res 2021;23:e19473. doi:10.2196/19473.

Kamel Boulos MN, Geraghty EM. Geographical tracking and mapping of coronavirus disease COVID-19/severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic and associated events around the world: how 21st century GIS technologies are supporting the global fight against outbreaks and epidemics. Int J Health Geogr 2020;19:8. doi:10.1186/s12942-020-00202-8.

Keyser JA, Baumrucker EP. Medicaid Telehealth Policies in Response to COVID-19. Congr Res Serv 2020:3.

Khan ZH, Siddique A, Lee CW. Robotics Utilization for Healthcare Digitization in Global COVID-19 Management. Int J Environ Res Public Health 2020;17:3819. doi:10.3390/ijerph17113819.

Mugambe RK, Mselle JS, Ssekamatte T, Ntanda M, Isunju JB, Wafula ST, et al. Impact of mhealth messages and environmental cues on hand hygiene practice among healthcare workers in the greater Kampala metropolitan area, Uganda: study protocol for a cluster randomized trial. BMC Health Serv Res 2021;21:88. doi:10.1186/s12913-021-06082-3.

OECD. Health resources - Health spending - OECD Data. The OECD 202. 1; 2021 http://data.oecd.org/healthres/health-spending.htm accessed August 11,.

Pan X, Ojcius DM, Gao T, Li Z, Chunhua Pan, Chungen Pan. Lessons learned from the 2019-nCoV epidemic on prevention of future infectious diseases. Microbes Infect 2020;22:86–91. doi:10.1016/j.micinf.2020.02.004.

Pan X-B. Application of personal-oriented digital technology in preventing transmission of COVID-19, China. Ir J Med Sci 2020;189:1145–6. doi:10.1007/s11845-020-02215-5.

Pryor RJ, Vokes R, Anderson D, Bearman G. Virtual infection prevention-The next frontier. Infect Control Hosp Epidemiol 2021:1–2. doi:10.1017/ice.2020.1404.

Ramnath VR, Hill L, Schultz J, Mandel J, Smith A, Morris T, et al. An In-Person and Telemedicine “Hybrid” System to Improve Cross-Border Critical Care in COVID-19. Ann Glob Health 2021;87:1. doi:10.5334/aogh.3108.

Scott BK, Miller GT, Fonda SJ, Yeaw RE, Gaudaen JC, Pavliscsak HH, et al. Advanced Digital Health Technologies for COVID-19 and Future Emergencies. Telemed E-Health 2020;26:1226–33. doi:10.1089/tmj.2020.0140.

Sokunbi OJ, Mgbajah O, Olugbemi A, Udom BO, Idowu A, Sanusi MO. Maintaining paediatric cardiac services during the COVID-19 pandemic in a developing country in sub-Saharan Africa: guidelines for a “scale up” in the face of a global “scale down. Cardiol Young 2020;30:1588–94. doi:10.1017/S1047951120003650.

Suppan L, Abbas M, Stuby L, Cottet P, Larribau R, Golay E, et al. Effect of an E-Learning Module on Personal Protective Equipment Proficiency Among Prehospital Personnel: Web-Based Randomized Controlled Trial. J Med Internet Res 2020;22:e21265. doi:10.2196/21265.

Varsavsky T, Graham MS, Canas LS, Ganesh S, Pujol JC, Sudre CH, et al. Detecting COVID-19 infection hotspots in England using large-scale self-reported data from a mobile application. MedRxiv Prepr Serv Health Sci 2020 2020.10.26.20219659.. doi:10.1101/2020.10.26.20219659.

Walensky RP, McQuillen DP, Shahbazi S, Goodson JD. Where Is the ID in COVID-19? Ann Intern Med 2020;173:587–9. doi:10.7326/M20-2684.

Williams SG, Fontaine RE, Turcios Ruiz RM, Walke H, Ijaz K, Baggett HC. One Field Epidemiologist per 200,000 Population: Lessons Learned from Implementing a Global Public Health Workforce Target. Health Secur 2020;18 S-113-S-118. doi:10.1089/hs.2019.0119.