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REVIEW

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# Communication, collaboration and contagion: "Virtualisation" of anatomy during COVID-19

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## Abstract

COVID-19 has generated a global need for technologies that enable communication, collaboration, education and scientific discourse whilst maintaining physical distance. University closures due to COVID-19 and physical distancing measures disrupt academic activities that previously occurred face-to-face. Restrictions placed on universities due to COVID-19 have precluded most conventional forms of education, assessment, research and scientific discourse. Anatomists now require valid, robust and easy-to-use communication tools to facilitate remote teaching, learning and research. Recent advances in communication, video conferencing and digital technologies may facilitate continuity of teaching and research activities. Examples include highly-interactive video conferencing technology, collaborative tools, social media and networking platforms. In this narrative review, we examine the utility of these technologies in supporting effective communication and professional activities of anatomists during COVID-19 and after.

**KEYWORDS**

anatomy, COVID-19 in lieu of medicine, embryology, medical education, medicine, surgery

## 1 | INTRODUCTION

SARS-CoV-2 causes coronavirus disease 2019 (COVID-19), a highly disruptive global pandemic that has adversely affected healthcare, economic and education systems internationally. The pandemic has prompted restrictive public health measures and physical distancing policies. As of April 2020, educational institutions, from primary to tertiary levels, have closed in 188 countries (Setiawan & Ilmiyah, 2020). UNESCO data report university and school closures have affected 91% of learners worldwide (Nicola et al., 2020; Taha, Abdalla, Wadi, & Khalafalla, 2020). Consequently, university closures and public health measures have precluded conventional forms of teaching, assessment, research and scientific discourse.

Until recently, anatomists relied on cadaveric prosections, virtual anatomy platforms and, importantly, face-to-face interactions for research and teaching activities (Gray & Walker, 2015). However, current limitations necessitate students, researchers and educators in anatomy worldwide to engage with alternative means of communication and to link these alternative communication tools with the practical aspects of acquiring anatomical knowledge. Despite challenges, such limitations present new opportunities, including the opportunity to develop new educational resources, upskilling of anatomists in new technologies and long-distance collaboration. Increased and accelerated adoption of current technologies and rapid innovation of new technologies are now required. Here, in this narrative review, we begin by reviewing advances made during previous pandemics. Following this, we review technologies, software and online platforms that have underpinned communication between anatomists during COVID-19 and that may endure thereafter.

## 2 | HISTORICAL ADVANCEMENTS MADE DURING PANDEMICS

Some historians, including David Herlihy and Robert Gottfried, argue that pandemics are watershed periods for education and science

(Gottfried, 2001; Herlihy, 2019). Prior to the Black Death (1346–1354), medieval education relied on teachings from Hippocrates, Aristotle and Galen.(Jouanna, 2010; Temkin & Straus, 1946) Physicians were proficient in oratory and natural philosophy (Hirai, 2011). However, a foundation in physical sciences such as anatomy and pathology were commonly lacking. Arising from this, physicians were poorly prepared to deal with the pandemic and the practices required of them to provide effective care. Crucially, medical theories such as humorism, which was taught widely and attributed disease to imbalances in four bodily fluids, failed to explain transmission of infectious diseases (Jouanna, 2010). It is reasonable to suggest that inadequate medical care contributed considerably to more than a third of the Western World's population dying during that period (Bowsky, 1978). Indeed, some authors argue that it was that the inability of medical theories to manage previously unidentified disease that led to subsequent undermining of public confidence in medicine (Herlihy, 2019).

The Black Death highlighted the inadequacies of medieval medical theories. Yet some postulate this acknowledgement may have accelerated changes already occurring in universities throughout Europe (Gottfried, 2001). For example, the University of Bologna, which produced prominent scholars such as Guy de Chauliac, was amongst the first in Europe to incorporate surgery into its curriculum and to reintroduce human dissections in the teaching of anatomy, something that had lapsed since the classical period (Bullough, 1958; Watters, 2013). During this period, surgery became integral to medical curricula, anatomists performed more cadaveric dissection, and anatomical texts increased in accuracy (Herlihy, 2019).

Many historians consider the Black Death as the accelerant in reformation of medical theories and divergence from Galenic tradition (Carmichael, Garcia-Ballester, French, Arrizabalaga, & Cunningham, 1996; French, Arrizabalaga, Cunningham, & García-Ballester, 2019; Ziegler, 2019). Although it is difficult to attribute causation of these developments to this pandemic, it is possible that societal factors, including plague and the 100 Years' War, generated necessity for more pragmatic and empirical approaches to medicine. In this way, changes in teaching and learning that had already begun in European universities were adopted both more widely and more quickly than may otherwise have occurred.

Acceleration of scientific advances during pandemics was not unique to the Black Death. Later, during the Great Plague of London (1665–1666), Sir Isaac Newton made several discoveries whilst forced to self-isolate, termed his *Annus Mirabilis*, or “year of wonders” (Osler, 1972a; Whiteside, 1966). Newton's scientific advances included a theory of color, foundational work in calculus, and early work for a theory of gravity. Biographers of Newton attribute his freedom from academic commitments as a key enabler during this period of intense productivity (Burke, 1990; Osler, 1972b). Examples of increased creativity during pandemics also exist in artistic fields. For example, in 1592, William Shakespeare started writing poetry to make a living in response to theatres closing due to a plague outbreak. During this period, he wrote *Venus and Adonis* and *The Rape of Lucrece*. During a later outbreak, in 1606, he wrote *Macbeth*, *King Lear*, and *Antony & Cleopatra* (Knights & Gray, 1996; Rowe, 1963).

More recent epidemics have resulted in similarly restrictive public health measures, but did not prompt widespread adoption of communication technologies. Examples include Severe Acute Respiratory Syndrome (SARS; 2002–2004), Middle East Respiratory Syndrome (MERS; 2012) and Influenza A virus subtype H1N1 (A/H1N1; 2009) (Tambyah, 2016). During SARS, some Chinese medical schools developed online educational platforms to deliver problem-based learning (Naylor, Chantler, & Griffiths, 2004; Patil & Chan Ho Yan, 2003). Many universities opted to use video conferencing in lieu of international travel (Lee, 2003). However, technologies such as integrated web cameras and high-speed internet were not ubiquitous. In addition, such epidemics were not global events, which may explain why technology solutions were not adopted universally.

## 3 | “VIRTUALIZATION” OF ANATOMY

COVID-19 has generated a global need for technologies enabling rapid communication, remote collaboration and scientific discourse. To ensure continuity of academic activities, universities require robust, easy-to-use communication tools to enable remote learning, research and professional activities. Recent advances in communication technology, such as video conferencing, online collaboration tools and online learning resources, now permit collaboration between academics, albeit in a fundamentally different way (Table 1). The following section outlines technologies and software currently available to anatomists.

### 3.1 | Communication and collaboration tools

Video conferencing technology may be applied to a range of academic activities, including teaching sessions, large group webinars, examinations, research meetings and academic conferences (Mutter & Marescaux, 2010). Recently, we conducted a viva voce examination in anatomy using video conferencing technology. Previously, this mode of examination was limited to “exceptional circumstances” by university charter. This approach offers many advantages, balanced against inherent limitations of video conferencing technology (Table 2). This project focused on the mesenteric organ, and used numerous 3D modalities to depict different anatomical regions (Byrnes, McDermott, & Coffey, 2019a; Byrnes, McDermott, & Coffey, 2019b). Video conferencing was optimally suited to displaying these modalities. Features such as whiteboarding, screen sharing, screen annotation, group chat and breakout rooms may also be used. These features, which remain largely underutilized, have potential to broaden the applications of video conferencing to anatomy teaching and learning generally.

Video conferencing has the potential to replace or supplement conventional forms of communication. Other fields, including in medicine and dentistry, have reported successful replacement of practical sessions using video conferencing (Aarnio, Rudenberg, Ellonen, & Jaatinen, 2000; Augestad & Lindsetmo, 2009; Chen, Hob-Dell, Dunn,

**TABLE 1** Summary of commonly-used technologies, software and online platforms supporting communication and collaboration between anatomists

| Name of technology | Source | Description |
|---|---|---|
| Communication and video conferencing tools | | |
| Zoom | Zoom Communications, Inc. San Jose, CA | Cloud platform for video and audio conferencing, collaboration, chat, and webinars across mobile devices, desktops and telephones. |
| Hangouts/ meet | Google, Inc. Mountain View, California | Online video conferencing apps that enable up to 30 users at once and dial in phone numbers. |
| Skype | Microsoft, Inc. Redmond, Washington | Telecommunications application and messaging platform that specializes in providing video chat and voice calls between computers, tablets and mobile devices. |
| Chime | Amazon, Seattle, Washington | Communications service that facilitates online meetings across your devices, as well as video conferencing, calls, and content sharing. |
| Webex | Cisco, Placer County, California | Cloud-based web and video conferencing service that enables global and virtual teams to collaborate on mobile devices and standards-based video systems in real time. |
| BigBlueButton | BigBlueButton, Ridgefield, Connecticut | Open-source web conferencing system providing solutions for remote teaching of students |
| Spaces | Avaya, Markham, Canada | Cloud-based video conferencing and meeting app that facilitates team collaboration online. |
| Collaboration platforms | | |
| Microsoft teams | Microsoft, Inc. Redmond, Washington | Communication and collaboration platform that combines video conferencing, content sharing, and application integration. |
| Gdrive/docs | Google, Inc. Mountain View, California | Cloud storage platform that enables collaborative editing of documents. |
| Slack | slack technologies, san Francisco, California | Collaboration hub facilitating messaging between team members, video conferencing, scheduling and content sharing. |

**TABLE 2** Advantages and disadvantages of video conferencing technologies for anatomy teaching and research

| Advantages | Disadvantages |
|---|---|
| • Involvement of international anatomists<br>• Time efficient<br>• Low-cost alternative to national/international travel<br>• Ability to present PowerPoint, video or raw data formats<br>• Increased focus on visual aspects of presentation<br>• Delegated chairperson can moderate session and mediate conversation<br>• Easy to reschedule or postpone meeting | • Time "lag" between participants<br>• Poor transmission of body language<br>• Time zone differences between participants<br>• Physical data (e.g., 3D printed models) cannot be presented<br>• Requires high-speed internet<br>• Risk of connection breakdown<br>• Licensing fees for universities<br>• Data protection and confidentiality concerns for patient or cadaveric data<br>• Less opportunity for networking |

Johnson, & Zhang, 2003; Gul, Wan, & Darzi, 1999). Clearly, compensation for loss of training hours and clinical experience during COVID-19 is feasible using telecommunications. Moszkowicz et al. recently reported using Google Hangouts (CA) for interactive medical education sessions (de Wolf & Birch, 2020). Likewise, Allsop et al. reported teleconferencing using Microsoft Surface Hub for anatomical teaching to medical students on placements (Allsop et al., 2020). Surface Hub is a digital whiteboard that enables anatomists to link into medical students on clinical attachment and to provide tutorials on pertinent clinical anatomy. Anatomists could apply such approaches broadly to small-group tutorials, practical exams, and clinical cases. Directly as a result of the COVID-19 restrictions we, at the University of Limerick, have, for the first time, been providing virtual anatomy lectures, tutorials and quiz's using a variety of video conferencing platforms to first and second year medical students. The topics covered will be assessed by online spotter exams using the "Practique" (Fry-IT Lt, London, United Kingdom) online assessment tool.

## 3.2 | Remote learning

Sociological studies characterize the current generation of learners (i.e., Generation Z) as digitally literate and highly connected (Geck, 2006; Strout, 2006; Turner, 2015). Surveys report high rates of engagement with technology, with average daily use of smartphones ranging from 3–8 hr (Ahmed, 2019). Emerging data indicate a readiness of current students to engage with technology-based solutions (Harlick & Halleran, 2015; Seemiller & Grace, 2017).

However, reproducing conventional anatomical teaching is challenging using digital media alone. Communication of three-dimensional concepts and tactile properties of structures cannot be conveyed readily in the online setting. Conversely, digital resources may allow the opportunity to present detailed, high-quality prosections, rare anatomical variants and, potentially, virtual dissection. Digital modelling may further enhance teaching of difficult anatomical concepts

(Byrnes, Walsh, Dockery, McDermott, & Coffey, 2019; Byrnes, Walsh, Lewton-Brain, McDermott, & Coffey, 2019; Peirce et al., 2014). Therefore, combining conventional approaches with digital resources may optimize learning yield. Furthermore, these technologies are scalable and may reduce cost to students and universities, facilitating less developed countries to access teaching resources. The challenges imposed by COVID-19 can be interpreted as a unique research opportunity to test new resources and modalities against conventional teaching.

Conventional methods of anatomical examination are resource- and time-intensive and, as such, have tended to be consistently cut in modern medical curricula. Design and invigilation of conventional prosection-based exams can reportedly last several days (Schubert, Schnabel, & Winkelmann, 2009). Interestingly, Dennick et al. found comparable performance between students taking conventional prosection-based exams and image-based online exams (Dennick, Wilkinson, & Purcell, 2009). Emerging evidence now supports integration of virtual dissections into anatomical curricula, yielding considerable savings in terms of time and money (Barrack, Horn, & Benninger, 2015; Pandya & Pandya, 2018; Redéen, Elmhester, Larsson, & Lindfors, 2014; Yammine & Violato, 2016).

COVID-19 may prompt anatomists to produce online learning resources. Collaborative efforts, at national or international levels, could facilitate large-scale online seminars (i.e., webinars). This offers flexibility not only to learners, but also educators. Furthermore, international experts could deliver specialist lectures at postgraduate level to researchers and medical professionals. Currently, online seminars or massive open online course (MOOCs) in anatomy are uncommon (Pickering & Swinnerton, 2017; Swinnerton, Morris, Hotchkiss, & Pickering, 2017). Swinnerton et al. suggest that medical professionals and surgical trainees would readily engage with webinars and MOOCs in anatomy (Swinnerton et al., 2017).

Longhurst et al. recently conducted a strength, weakness, opportunity, threat analysis of COVID-19 utilising the perspectives of anatomical educators in the United Kingdom and Republic of Ireland (Longhurst et al., 2020). Respondents in the study identified COVID-19 as an opportunity to produce new resources and engage in collaborative efforts. However, concerns were raised regarding time constraints placed on both students and educators. Clearly, production of new resources and adaptation to technologies will be challenging. However, if designed appropriately and used efficiently, these technologies have potential to decrease overall workload for educators and broaden opportunities for dissemination.

### 3.3 | Decentralizing research activities

Closure of laboratories and inability to conduct face-to-face research meetings prompts researchers to innovate new modes of communication, collaboration and scientific discourse. Frequently, activities in academia rely upon face-to-face interactions with peers, students and researchers. Academic conferences, local research meetings and journal clubs are other examples of activities that conventionally occur face-to-face. Physical distancing measures now precludes many of these activities. However, with reduced registration and travel costs, a move toward virtual activities may favour early career researchers and those from economically deprived regions (Maloney et al., 2017).

Many researchers may now have to shift their research focus from wet laboratories with university closures and physical distancing policies. Increased availability of open-access anatomical datasets now permits research that may be readily tested for validity. Examples of datasets include the visible human and embryo projects, the digital embryo consortium, as well as radiological datasets from the cancer imaging archive (Clark et al., 2013; Park, Chung, Hwang, Shin, & Park, 2006; Cork & Gasser, 2012; Spitzer & Whitlock, 1998; Zhang et al., 2004; Zhang, Heng, & Liu, 2006). Open-access datasets enable anatomists to conduct research activities with limited funding or resources. Moreover, usage of these datasets typically bypasses delays incurred by ethics committees and institutional review boards.

Collaborative research is increasing in the medical field, where multicentre studies are conducted at national and international levels (Chari et al., 2018; Fowler, Al Omran, Pidgeon, Jafree, & Agha, 2016, 2016; Pidgeon et al., 2018; Sainsbury et al., 2019). Notably, many collaborations are led by trainees and facilitated using communication technologies such as video conferencing (Sainsbury et al., 2019). Despite growing popularity in medical research, collaborative groups have not yet been popularized in the anatomical field. Given availability of open-access datasets, large-scale collaborative research is feasible in anatomy.

Arguably, social media has transformed dissemination of information. Anatomists have engaged with platforms including Twitter, ResearchGate and Publons (Logghe et al., 2018; Ortega, 2017; Ovadia, 2014; Smith, 2016; Yu, Wu, Alhalabi, Kao, & Wu, 2016). These platforms provide effective means of networking, enabling large-scale, rapid and international communication between researchers. Small research groups may benefit most, with greater opportunities for networking and collaboration (Choi, Im, & Hofstede, 2016; Holmberg & Thelwall, 2013). Furthermore, social media may act as a new form of peer review. However, this form of unregulated peer review and promotion of articles without declared conflicts of interest may hamper progress.

## 4 | FUTURE DIRECTIONS

Limited availability of cadaveric specimens and time and resource constraints have, for many years now, been prompting anatomists to adopt new technologies for education and research (Ghosh, 2017). However, as anatomy is a three-dimensional field, integration of new technologies remains challenging especially if remote learning is to play a prominent role in future anatomical education. Undoubtedly, conventional approaches such as cadaveric dissection, enable direct appreciation of shape and spatial relationships between structures. Successful integration of new technologies into anatomical curricula require such technologies to address the three-dimensional nature of anatomy and the spatial relationships of body structures (Yammine & Violato, 2015).

Despite recent advances, further improvements are required to increase the utility of technology. Enhancements in dependability, costing and audio-visual quality would increase the uptake of video conferencing platforms. Newer technologies include virtual reality, augmented reality and three-dimensional printing (Sun & Li, 2018; Vaccarezza & Papa, 2014). Currently, most applications of 3D-printing have occurred in the research setting but with improved availability and decreased cost, 3D-printers may enable students to remotely print anatomical models. These newer media optimally address many of the three-dimensional aspects of anatomical teaching. However, printing of anatomical models should be performed cautiously and with due cognizance of the environmental impact of printer materials. Potential benefits should be weighted up against environmental costs. As such, printing of models may be limited to very specialist areas where the user is likely to get a long-term benefit from repeated use of the model.

Virtual reality systems have improved substantially in the last decade. Widely accessible platforms include Daydream (Google, Inc. Mountain View, California), Gear VR (Samsung, Seoul, South Korea) and HoloLens (Microsoft, Inc. Redmond, Washington) (Erolin, 2019; Maniam et al., 2020; Moro, Stromberga, & Stirling, 2017; Pratt et al., 2018). These platforms enable viewers to interact with virtual environments that contain anatomical prosections or reconstructions. Appreciation of spatial relationships is possible due to binocular vision (Trelease, 1998). Moreover, anatomically remote regions, such as the pelvis, are easier to visualise compared to cadaveric prosections (Gaasedelen, Deakyne, Iles, & Iaizzo, 2017; Zheng, 2019). It is also possible to embed three-dimensional models into conventional text using QR (Quick Response) codes and allow the reader to access three-dimensional models using a smartphone or virtual reality headset. For example, we recently combined the SketchFab (Sketchfab Inc., New York, NY) online platform with QR codes in a recently published reference textbook to convey 3D anatomical models in conventional text (Coffey, Dockery, Moran, & Heald, 2017).

However, rapid adoption of new technologies is not risk-free. Recently, the Human Tissue Authority (London, United Kingdom) released a statement regarding the use of images of cadaveric prosections online and reiterated the need for dignity of donors (Franchi, 2020). Consent processes must, therefore, ensure donors are informed if images are to contribute to online materials.

## 5 | DISCUSSION

COVID-19 presents new opportunities for anatomists, balanced against challenges. Changes to anatomical curriculae typically take decades. However, COVID-19 prompts anatomists to rapidly adapt to new technologies. Adoption of communication technologies may boost efficiency and redouble collaborative efforts.

Much like during the Black Death, many of these changes were already occurring in universities worldwide. During COVID-19, anatomists must rely on these technologies as a primary mode of communication. The experience gained during this period may act as the principal determinant for a continued reliance on virtual technologies in the anatomical sciences. Notably, Italian universities are amongst the first to adapt. For example, the University of Bologna, having previously undergone aforementioned changes during the Black Death, have now transferred over 90% of classes online during COVID-19. Suspension of body donor programs due to COVID-19 are likely to further encourage anatomists to use technology enhanced learning. Many centres around the world, including the University of Limerick Medical School have, for many years now, been using virtual dissection technology as a replacement for actual dissection. As such, it is important to rethink modes of delivering anatomical curriculae after COVID-19.

However, caution is required when adopting new technologies. Digital technologies are not without limitations, and where possible, limited face-to-face interactions should be maintained whilst adhering to public health advice. The delivery of educational and research content through such technologies may be limited by technical difficulties, impaired internet connection or poor resources at either end. However, given recent rapid advances in these technologies over recent decades, it is feasible that advances of similar magnitude could be replicated, enabling truly unimpeded communication and collaboration between anatomists internationally. Notwithstanding, the COVID-19 pandemic could act as a catalyst for widespread adoption of these technologies, and by doing so, generate a need for further refinement and technological innovation in this field.

The Canadian media theorist Marshall McLuhan first coined the term “global village” for “a global coexistence altered by transnational commerce, migration, and culture” (Levinson, 1993). Arguably, new media enable a global village for anatomists worldwide. Technology facilitates anatomists to form a digital community and develop creative solutions. Clearly, COVID-19 has accelerated this process of adaptation to existing technologies.

## 6 | CONCLUSION

Previous pandemics and associated public health measures have challenged academia. However, restrictions provide an impetus to innovate and develop creative solutions. The disruptive nature of pandemics prompts academics to work creatively and provide alternative solutions, many of which have advantages. COVID-19 may become a boon for collaboration and encourage alternative forms of communication within the anatomical community. Such disruption related to COVID-19 may result in long-lasting adoption of modern communication tools.

## AUTHOR CONTRIBUTORS

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