



Could COVID-19 Trigger a Rebirth in Anatomy Education? A Glimpse of Anatomists' Responses to Pandemics of the Past and Present

N. Naidoo¹ · K. S. Satyapal² · L. Lazarus²

Accepted: 8 February 2021 / Published online: 15 February 2021

© The Author(s), under exclusive licence to Springer Nature Switzerland AG part of Springer Nature 2021

Abstract

Pandemics are nothing unusual but indeed lead to devastating effects that play a pivotal role in reshaping human history. The COVID-19 outbreak is currently responsible for major educational crises globally as most of the world has been faced with a mandated lockdown, and forced closure of educational institutions, including medical colleges. Anatomists have therefore been challenged to unlock technology in effort to achieve best deliverables for their discipline, without the use of traditional teaching aids such as the cadaver, osteological banks, prosected specimens, models, and microscopic slides. At present, the virtual classroom is the only option for the anatomist, thereby omitting vital aspects of the hidden curriculum such as ethical-reasoning, empathy, respect, professionalism, interpersonal, and communication skills. As body donations dwindle, the era of teaching in a cadaverless environment is upon us. This marks the beginning of a paradigm shift in education and research for anatomists worldwide. Given the variable pathological-morphological presentation in COVID-19-related deaths, it is also likely that the autopsy component of anatomic pathology will be resuscitated to demystify the underlying mechanisms of the virus. Since COVID-19 may never disappear completely, we would like to recommend that international anatomical societies collectively reach out to statutory bodies to devise a standardized method of teaching anatomy, employing readily available cost-effective resources, in the face of pandemics. However, if anatomy as a discipline has survived a millennium, surely anatomists can fight the “scourges” that have plagued them as various perspectives have been bandied about to welcome in a new normal.

Keywords Anatomy education · Cadaveric dissection · COVID-19 · Future · Pandemics

Introduction

As a pandemic sails through its sequential phases, academic institutions are challenged to reflect, strategize, implement, and most importantly adapt. Indeed, this herculean task evokes a plethora of emotions and questions for both students and faculty alike.

In light of the disruptive innovation era, academic institutions worldwide may consider themselves blessed to be at the

forefront of technological advances as they tackle the educational challenges posed by the present COVID-19 pandemic. The stark reality of these advances is further appreciated when paralleled to an historical account of the Spanish Flu pandemic from the 1918 November edition of the Canadian Dalhousie Gazette: “This year the college curriculum seems doomed to interruption, much to the joy of the slothful, but decidedly to the inconvenience of those who really want to learn something before they leave Dalhousie ... The shut-down lasted for nearly five weeks and, besides driving the faculty to despair, did not bring any satisfaction to the holiday inclined as no movies were open and the rain was practically continuous” [1]. While at the same time, further afield in Kansas, a student embraced the supposed normalcy of life as the global public health emergency continued: “Ralph and I are fine, and have not gotten the “flue” yet altho it is pretty bad down here at present ... I certainly like my school work and time goes so fast, have all my classes in the forenoon but the lessons are so long it takes all P.M. and until 10 P.M. to prepare lessons for next day” [2]. As articulated by these historical pieces, irrespective of time or

This article is part of the Topical Collection on *COVID-19*

✉ N. Naidoo
nerissa.naidoo@mbu.ac.ae

¹ Department of Basic Medical Sciences, College of Medicine, Mohammed Bin Rashid University of Medicine and Health Sciences, Dubai Health Care City, P.O. Box 505055, Dubai, United Arab Emirates

² Discipline of Clinical Anatomy, College of Health Sciences, University of KwaZulu-Natal, Durban, South Africa

place, the changing terrain of education is inevitable in the face of a pandemic.

When we look through the lens of the current COVID-19 pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (i.e. SARS-CoV-2) [3], the field of view of the present state of anatomy education is magnified and poses the question: “Will the COVID-19 pandemic shake up the global anatomy education system?”. In an attempt to answer this question, it is noteworthy to trace the fate of anatomy education through the history of pandemics.

Anatomy Education Through the History of Pandemics

Although the discipline of anatomy is often considered to be anachronistic due to its association to cadaveric dissection, it is no stranger to reform in the changing landscape of pandemics [4]. With the arrival of the Black Death (i.e., Bubonic Plague) in 1346, came the establishment and growth of medicine as a science [5]. Until this time, cadaveric dissection was seldom performed in anatomy education and constituted a crime as it was banned through the issuance of a papal bull by Pope Boniface VIII in the early 1300s [6]. However, as a few Bolognese medical schools related this injunction to a “religion-induced medical ignorance”, they supported biannual public dissection events [7]. These events were held in makeshift venues and were facilitated by three individuals: a surgeon who dissected a corpse provided by the Duke of Anjou; a Latin-speaking general physician who communicated each step of the dissection to the audience; and a prosector who indicated the dissected structures—a theatrical mental image comparable to “The Anatomy Lesson” painted by Rembrandt [7].

Changes soon became apparent as the Black Death abruptly swept away lives, more rapidly than burial grounds could accommodate [6]. As this spurred an inquiry into the mechanism of the virus, Pope Clement VI issued a decree that called for autopsies of plague victims, which then transformed the stigma associated with cadaveric dissection, simultaneously providing physicians with the opportunity to learn about human anatomy and refine their surgical skills [5, 6]. This in-depth delve into human anatomy through dissection offered a valuable complement to the existing pictorial treatises of Galen.

Approximately 500 years later, the cholera pandemic (i.e., Asiatic flu) struck Britain [8]. Contrary to the need to study the diseased body, as identified during the Black Death, the bodies of deceased cholera victims were utilized as learning resources to teach dissection to an increasing population of medical students [9]. Unfortunately, this need to educate clashed with body snatching, thereby calling for the Anatomy Act to be passed in Britain [8]. Cadaveric dissection in anatomy

education then became bound by red tape and restrictions due to the ethico-legal framework surrounding cadaver procurement and disposal.

One and a half centuries later, the HIV/AIDs pandemic dominated the headlines. Unlike the Black Death and cholera pandemics, this virus was marked by concern, fear, uncertainty, and stigma [10]. Medical students raised the question about the risk of accidental infection during cadaveric dissection or contact with infected tissue or fluid [10]. As a result, the implementation of safe work practices in dissection halls and mortuaries was coupled with awareness campaigns to communicate the potential risks [11].

Thus, as we travel through the history of pandemics, it is evident that Still’s belief that cadaveric dissection “... will help you to verify your mental conception of the body’s structure” stood the test of time in many medical schools [12]. But as we return to the present COVID-19 pandemic, it is also useful to highlight the current response of anatomy educationists and to outline the challenges encountered.

How Did Anatomists Respond to COVID-19?

When the news of increasing COVID-19 cases unfolded across the globe, it was unexpected that it would be a while before the “instagrammable” hashtag “just another day in the life of a medical student” would be posted. Universities monitored the evolving situation closely and undertook unprecedented measures before closing their doors and shifting to online distance learning platforms [13–15].

While most basic science disciplines easily adapted to this modality, the discipline of anatomy is unique as its conventional pedagogical approaches are founded on the hands-on experience gained in the dissection hall [15]. Interestingly, anatomy departments responded by employing the mandated COVID-19 lockdown as a catalyst to innovate and digitize anatomy education. To date, the anatomical community has responded relatively well to the COVID-19 crisis by rapidly finding innovative ways to alter pedagogical methods, share resources, and support each other to facilitate the transition to online platforms [16]. This entry into the digital realm embraced the concept of anywhere-anytime learning and instituted deep learning strategies, inadvertently promoting learner autonomy in a discipline that was traditionally built on surface learning strategies [17].

During this time, countries such France, the UK, Republic of Ireland, Australia, and New Zealand, successfully disseminated blended learning approaches (i.e., mix of synchronous and non-synchronous activities) via distance learning platforms, with many viewing it as the ideal opportunity to upskill staff and students in novel technologies and resources [14, 15, 18]. Undeniably, challenges pertaining to curriculum and schedule changes, availability and accessibility of

infrastructure and resources, increased workload, student attendance, commitment and engagement, and staff adaptability were noted [14, 15]. Although many relied on three-dimensional virtual anatomy modalities and digitized cadaveric resources to create a simulacrum of a classical *in vivo* dissection session, academicians expressed concern regarding the absence of the cadaver as the primary pedagogical obelisk of anatomical education [14, 19]. In the darkness of COVID-19, most medical students and residents have lost not just the cadaver but a number of other learning modalities such as models, museum specimens, bones, and microscopic slides due to the mandated lockdown, which may potentially impact their knowledge in anatomy [20].

To dissect or Not to Dissect?

Case in point, several medical schools have long stopped the practice of cadaveric dissection and have instead reimagined anatomy education through the world of digital technology [13, 21]. In fact, undergraduate students at a non-dissection-based medical school reflected on the variety of digital educational resources available to bridge the gap left by the removal of cadaveric dissection [22]. That being said, cadaveric dissection embodies kinesthetic learning and provides a route of investigation for the student; hence, it is necessary to evaluate how the absence of that first incision will affect the thought experiment [22, 23]. If cadaveric dissection becomes obsolete, does this mean we are divesting students of intangible devices of imagination? And if anatomy instruction is indefinitely delivered via online distance learning modalities, are we stepping back into the pre-Black death era when cadaveric dissection was not accepted nor routinely practiced in the delivery of anatomy education?

Indeed, we find ourselves in a time during which undergraduate medical curricula have evolved from the conventional discipline-based model to the contemporary integrated systems-based model that incorporates core non-discipline-related soft competencies [12, 24, 25]. However, the experience gained in the dissection hall also plays a pivotal role in enhancing ethical reasoning, empathy, respect, professionalism, and interpersonal and communication skills—all of which are refined through this rite of passage into medical school [12, 26]. Since many students consider the cadaver to be their first patient or first teacher, we may inquire who will now uphold that role with the transition to the digital realm, how will the transformed exposure affect the student in the physical examination of surface anatomy during the clerkship and post-clerkship years, and if there will be an alternate vehicle to instill core skills in surgical residency [13, 27].

McGarvey et al. [28] highlighted the need for cadaveric dissection which helps to incorporate a plethora of useful skills that are critical to the development of a student across

the spectrum of medical education. Dissection enables a medical student to appreciate the concept of variability and prepares them to accept the anatomical minutiae as they present themselves in the dissected body, rather than developing a narrow vision or fixed attitude, which is the case when they come across anatomy in the form of reconstructed images. Dissection also encourages a student to trust his/her own observation skills, thereby reflecting upon individual learning and critical thinking which are key ingredients toward building clinical ability. Furthermore, the dissection laboratory also offers an opportunity to hone communication skills within peer groups, which could be beneficial later on in students' careers while dealing with patients [29, 30].

Where Does the Future Lie?

As anatomy education transforms digitally, there is a potential risk of widening the digital divide due to the demographic and socio-economic challenges faced in developing countries, concomitantly increasing the polarization between developed and underdeveloped nations. Further, with social distancing measures continuing to take precedence in all settings, it is also suspected that virtual universities may become a common fixture in the post-pandemic world and may attract students to apply and enroll in cost-effective local programs. This may heighten the financial burden of the large, elitist universities as the number of international students dwindles, leaving behind bodiless dissection halls and dust-laden anatomy museums.

Despite these uncertainties and reservations, positive trends are also likely to arise in anatomy education as a result of the COVID-19 pandemic. Acquiring anatomy knowledge through digital platforms may liberalize learning to become a part of daily lifestyle as opposed to a rigid practice. It may spark collaborations between academic institutions and the tech industry, thereby driving innovation and enrichment in the clinical environment through a common educational goal.

Ghosh [26] stressed that there is general consensus that medical science cannot do without anatomical knowledge, whereas anatomy teaching on the other hand is incomplete without dissection. The International Federation of Association of Anatomists (IFAA) has offered guidelines on important aspects of the handling of bodies during the coronavirus pandemic. The guidelines were produced and shared in good faith for anatomists who wish to continue their dissection programs during the pandemic. However, most medical institutions have denied accepting bodies during this pandemic, contributing to the already dwindling numbers in body donor programs [20]. Moreover, does this begin to suggest that a grim future lies ahead for established body bequest programs?

Likewise, dissection-based teaching alone cannot fulfill all the needs of modern medical curricula and hence must be

complemented with novel teaching/learning methods. An education model that incorporates the interdependability of the different teaching/learning methods in anatomy, with human cadaveric dissection forming the core, is probably the future of anatomical sciences education. We will also need to evaluate the accuracy of new assessment tools that we are now compelled to employ. In addition, the course of research direction may be forced to change. One of the unintended consequences may also include the definitive address, under appropriate stewardship, of various issues relating to socio-cultural and medico-legal controversies in the use of human tissue for teaching and research.

On a similar front, the dissection laboratory also shifts the anatomical gaze from the surface of organs to a clinical gaze focused on lesions within the depths of organs, thus opening the door to the practice of autopsy in the discipline of anatomic pathology [31, 32]. Although texts of pathological anatomy were available as early as the eighteenth century, it was the Oslerian philosophy that prompted the surge in autopsy teaching and afforded autopsy its central role in medical education at the start of the twentieth century [33, 34]. Not only did this cultivate a deeper understanding of the anatomy and pathology in view of the patient's clinical history, but it also seamlessly delivered the "hidden curriculum" of life while serving as a quality control mechanism for the pathologist's practice [35–37]. In addition, the macroscopic features revealed by the corpse during autopsy were considered to be essential pieces of clinico-pathological knowledge harbored by the "agency of the dead", fostering skills such as examination, deductive reasoning, and diagnosis [38, 39].

However, recent decades have seen the demise of autopsy rates in educational and hospital practices, owing, but not limited to, advanced diagnostic modalities, religious and cultural diversity of population groups, organ retention scandals and the accompanying negative stigma, pathologists' apathy, curricular reform necessitated by the time allocated to emerging disciplines, increasing departmental budgetary demands, prevailing legislation and the physician's distress with obtaining autopsy consent from the bereaved family [33, 35, 40, 41]. To this end, many institutions have veered down the pathway of technological solutions, incorporating web-based and immersive virtual reality simulators, eAutopsy, and/or video teleconferencing of lives cases [42–44]. These alternatives have proven to be especially useful in the diagnosis of neurodegenerative diseases as they allow for the training of brain autopsy when the availability of real specimens is limited [42]. Similarly, the study conducted by Talmon et al. [44] reinforced the effectiveness of the eAutopsy but highlighted the apparent lack in emotional impact and hands-on experience. In terms of the medico-legal field, training on web-based simulators has provided users with a logical approach to execute investigation and interpret forensic findings [43]. Moreover, through novel imaging modalities, pathology can

now be examined at the molecular level, eliminating the need to dissect the corpse, and replacing anatomic pathology with molecular pathology [45].

On the contrary, while a few pathologists at the 2014 meeting of the Association of Pathology Chairs motioned for the abolishment of autopsy from the educational setting, the Autopsy Working Group later declared that its practice is integral to medicine and endorsed it as a pivotal component of anatomic pathology residency programs, with further recommendations to revolutionize it to current practice and employ uniform digitization [46].

Yet, this recommendation may not be the only resuscitating factor for the practice of autopsy as the COVID-19 pandemic is likely to bring the promise of a new dawn. In fact, Yasinski [47] reported the ensuing necessity of autopsy amid the COVID-19 pandemic and the potentially renewed respect for the pathologist's work. To date, several COVID-19 autopsy registries have been established worldwide to help gain knowledge about this new virus and to facilitate global pandemic control [48]. In light of the variable pathological-morphological presentation in COVID-19-related deaths, one particular autopsy study proposed a four-level classification scheme to account for this variability in deaths [49]. Along with the creation of an effective disease catalogue, as a HG3 pathogen, investigation of COVID-19-related deaths also requires focus on risk assessment, interpretation of the findings, universal precautions, and standard operating procedures [47, 50, 51]. Hence, the return and practice of autopsy may be the key to demystify the underlying mechanisms causing organ injury of COVID-19-related cases, thus developing clinical management and effective treatment strategies, with the ultimate goal of decreasing mortality.

Conclusion

However, with the above in mind, as pure anatomists, we remain advocates of cadaveric dissection in anatomy instruction. In addition to knowledge and skills, it is evident that the soft competencies assimilated during the dissection hall experience are keys to practice medicine. As warned by the World Health Organization [3], COVID-19 may never disappear completely; therefore, we would like to recommend that anatomical societies worldwide collectively reach out to statutory bodies to devise a standardized method of teaching anatomy in the face of pandemics that employs readily available cost-effective resources. Global acceptance will also assist to establish a benchmark of required competencies and sustain world university rankings.

The concept of medical curricula incorporating possible cadaverless anatomy programs will historically transition the discipline and will mark the beginning of a paradigm shift in education and research for anatomists globally. If anatomy has

survived a millennium, surely anatomists can fight the “scourges” that have plagued their discipline since various perspectives have been bandied about to welcome in a new normal.

Code Availability Not applicable

Authors' Contributions All authors contributed to the development and finalization of the manuscript.

Data Availability Not applicable

Declarations

Ethics Approval Not applicable

Consent to Participate Not applicable

Consent for Publication The authors provide consent for publication.

Conflicts of Interest The authors declare that they have no conflict of interest.

References

- Mitchell JH. A long rest for the weary. *The Dalhousie Gazette*. November 1918;1918(27):1–8.
- Kambhampaty AP. 'It is pretty bad down here at present.' what we can learn from a letter written just after the height of the 1918 flu pandemic. *TIME*. 2020.
- Organization WH. WHO Director-General's remarks at the media briefing on 2019-nCoV on 11 February 2020. In: Ghebreyesus TA, editor. Geneva: World Health Organization; 2020.
- Turney BW. Anatomy in a modern medical curriculum. *Ann R Coll Surg Engl*. 2007;89(2):104–7. <https://doi.org/10.1308/003588407X168244>.
- Legan JA. The medical response to the Black Death [Senior Honours Project]. Virginia: James Madison University Scholarly Commons; 2015.
- Inglis-Arkeel E. How the Black Death advanced medical science, With Help from the Pope. 2015. <https://io9.gizmodo.com/how-the-black-death-advanced-medical-science-with-help-1718448184>. 2020.
- Byrne JP. *Encyclopedia of the black death*. ABC-CLIO; 2012.
- Aberth J. *Plagues in world history*. Lanham: Rowman & Littlefield Publishers INC; 2011.
- Burrell S, Gill G. The Liverpool cholera epidemic of 1832 and anatomical dissection—medical mistrust and civil unrest. *J Hist Med Allied Sci*. 2005;60(4):478–98. <https://doi.org/10.1093/jhmas/jri061>.
- Ruggiero M, Galletti MP, Pacini S, Punzi T, Morucci G, Gulisano M. On the risk of contracting AIDS at the dissection table. *Ital J Anat Embryol*. 2009;114(2-3):97–108.
- Prayer Galletti M, Bauer HH. Safety issues in didactic anatomical dissection in regions of high HIV prevalence. *Ital J Anat Embryol*. 2009;114(4):179–91.
- Houser JJ, Kondrashov P. Gross anatomy education today: the integration of traditional and innovative methodologies. *Mo Med*. 2018;115(1):61–5.
- 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(3):312–5. <https://doi.org/10.1002/ase.1966>.
- Longhurst GJ, Stone DM, Duloherly K, Scully D, Campbell T, Smith CF. Strength, weakness, opportunity, threat (SWOT) analysis of the adaptations to anatomical education in the United Kingdom and Republic Of Ireland in response to the Covid-19 pandemic. *Anat Sci Educ*. 2020;13(3):301–11. <https://doi.org/10.1002/ase.1967>.
- Pather N, Blyth P, Chapman JA, Dayal MR, Flack N, 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(3):284–300. <https://doi.org/10.1002/ase.1968>.
- Evans DJR, Bay BH, Wilson TD, Smith CF, Lachman N, Pawlina W. Going virtual to support anatomy education: a STOPGAP in the midst of the Covid-19 pandemic. *Anat Sci Educ*. 2020;13(3):279–83. <https://doi.org/10.1002/ase.1963>.
- Smith CF, Martinez-Alvarez C, McHanwell S. The context of learning anatomy: does it make a difference? *J Anat*. 2014;224(3):270–8. <https://doi.org/10.1111/joa.12089>.
- 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(6):927–8. <https://doi.org/10.1002/ca.23601>.
- Habicht JL, Kiessling C, Winkelmann A. Bodies for anatomy education in medical schools: an overview of the sources of cadavers worldwide. *Acad Med*. 2018;93(9):1293–300. <https://doi.org/10.1097/ACM.0000000000002227>.
- Singal A, Bansal A, Chaudhary P. Cadaverless anatomy: darkness in the times of pandemic Covid-19. *Morphologie*. 2020;104:147–50. <https://doi.org/10.1016/j.morpho.2020.05.003>.
- McMenamin PG, McLachlan J, Wilson A, McBride JM, Pickering J, Evans DJR, et al. Do we really need cadavers anymore to learn anatomy in undergraduate medicine? *Med Teach*. 2018;40(10):1020–9. <https://doi.org/10.1080/0142159X.2018.1485884>.
- Patel SB, Mauro D, Fenn J, Sharkey DR, Jones C. Is dissection the only way to learn anatomy? Thoughts from students at a non-dissecting based medical school. *Perspect Med Educ*. 2015;4(5):259–60. <https://doi.org/10.1007/s40037-015-0206-8>.
- Anand MK, Singel TC. A comparative study of learning with “anatomage” virtual dissection table versus traditional dissection method in neuroanatomy. *Ind J Clin Anat Physiol*. 2014;4:177–80.
- Arantes M, Ferreira MA. Changing times in undergraduate studies on neuroanatomy. *Revista Brasileira de Educacao Medica*. 2016;40(3):423–9.
- Papa V, Vaccarezza M. Teaching anatomy in the XXI century: new aspects and pitfalls. *ScientificWorldJournal*. 2013;2013:310348–5. <https://doi.org/10.1155/2013/310348>.
- Ghosh SK. Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. *Anat Sci Educ*. 2017;10(3):286–99. <https://doi.org/10.1002/ase.1649>.
- Winkelmann A, Guldner FH. Cadavers as teachers: the dissecting room experience in Thailand. *BMJ*. 2004;329(7480):1455–7. <https://doi.org/10.1136/bmj.329.7480.1455>.
- Mc Garvey MA, Farrell T, Conroy RM, Kandiah S, Monkhouse WS. Dissection: a positive experience. *Clin Anat*. 2001;14(3):227–30. <https://doi.org/10.1002/ca.1037>.
- Lempp HK. Perceptions of dissection by students in one medical school: beyond learning about anatomy. A qualitative study. *Med Educ*. 2005;39(3):318–25. <https://doi.org/10.1111/j.1365-2929.2005.02095.x>.
- Robbins BD, Tomaka A, Innis C, Patterson J, Styn G. Lessons from the dead: the experiences of undergraduates working with cadavers. *Omega (Westport)*. 2008;58(3):177–92. <https://doi.org/10.2190/om.58.3.b>.

31. Firth J. Covid-19 current advice for pathologists. *Pathologica*. 2020;112(2):55–6. <https://doi.org/10.32074/1591-951X-12-20>.
32. Rae G, Cork JR, Karpinski AC, McGoey R, Swartz W. How the integration of pathology in the gross anatomy laboratory affects medical students. *Teach Learn Med*. 2017;29(1):101–8. <https://doi.org/10.1080/10401334.2016.1194761>.
33. O'Grady G. Death of the teaching autopsy. *BMJ*. 2003;327(7418):802–3. <https://doi.org/10.1136/bmj.327.7418.802>.
34. van den Tweel JG, Taylor CR. A brief history of pathology: preface to a forthcoming series that highlights milestones in the evolution of pathology as a discipline. *Virchows Arch*. 2010;457(1):3–10. <https://doi.org/10.1007/s00428-010-0934-4>.
35. Bamber AR, Quince TA. The value of postmortem experience in undergraduate medical education: current perspectives. *Adv Med Educ Pract*. 2015;6:159–70. <https://doi.org/10.2147/AMEP.S46669>.
36. de Campos FP, Rocha LO. The pedagogical value of autopsy. *Autops Case Rep*. 2015;5(3):1–6. <https://doi.org/10.4322/acr.2015.011>.
37. Rueckert J. Elimination of the autopsy requirement by CMS. *N Engl J Med*. 2020;382(7):683–4. <https://doi.org/10.1056/NEJMc1915417>.
38. Bronfen E, Goodwin SW. *Death and representation*. Baltimore: The John Hopkins Press; 1993.
39. Horsley P. 'How dead dead the dead are': sensing the science of death. *Qualitative Research*. 2012;12(5):14. <https://doi.org/10.1177/1468794112447723>.
40. Hamza A. Declining rate of autopsies: implications for anatomic pathology residents. *Autops Case Rep*. 2017;7(4):1–2. <https://doi.org/10.4322/acr.2017.036>.
41. McNamee LS, O'Brien FY, Botha JH. Student perceptions of medico-legal autopsy demonstrations in a student-centred curriculum. *Med Educ*. 2009;43(1):66–73. <https://doi.org/10.1111/j.1365-2923.2008.03248.x>.
42. Choi I. Autopsy brain removal training using virtual reality simulation. *Journal of Biocommunication*. 2019;43(2). <https://doi.org/10.5210/jbc.v43i2.10225>.
43. Schmeling A, Kellinghaus M, Becker JC, Schulz R, Schafer A, Pfeiffer H. A web-based e-learning programme for training external post-mortem examination in curricular medical education. *Int J Legal Med*. 2011;125(6):857–61. <https://doi.org/10.1007/s00414-011-0613-2>.
44. Talmon GA, Czamecki D, Bernal K. The eAutopsy: an effective virtual tool for exposing medical students to the postmortem examination. *Am J Clin Pathol*. 2014;142(5):594–600. <https://doi.org/10.1309/AJCP9TGI0GBIVBYK>.
45. Stempsey WE. The penetrating gaze and the decline of the autopsy. *AMA J Ethics*. 2016;18(8):833–8. <https://doi.org/10.1001/journalofethics.2016.18.8.msoc1-1608>.
46. Davis GG, Winters GL, Fyfe BS, Hooper JE, Iezzoni JC, Johnson RL, et al. Report and recommendations of the association of pathology chairs' autopsy working group. *Acad Pathol*. 2018;5:2374289518793988. <https://doi.org/10.1177/2374289518793988>.
47. Yasinski E. Autopsy rates were falling for years. Then Covid-19 came along. Blum, D., Massachusetts. 2020. <https://undark.org/2020/10/21/covid-19-autopsies/>. Accessed 28 December 2020.
48. von Stillfried S, Bulow RD, Rohrig R, Knuchel-Clarke R, Boor P, DeRegCovid. Autopsy registry can facilitate COVID-19 research. *EMBO Mol Med*. 2020;12(8):e12885. 10.15252/emmm.202012885.
49. Edler C, Schroder AS, Aepfelbacher M, Fitzek A, Heinemann A, Heinrich F, et al. Dying with SARS-CoV-2 infection-an autopsy study of the first consecutive 80 cases in Hamburg, Germany. *Int J Legal Med*. 2020;134(4):1275–84. <https://doi.org/10.1007/s00414-020-02317-w>.
50. Hanley B, Lucas SB, Youd E, Swift B, Osborn M. Autopsy in suspected COVID-19 cases. *J Clin Pathol*. 2020;73(5):239–42. <https://doi.org/10.1136/jclinpath-2020-206522>.
51. Sperhake JP. Autopsies of COVID-19 deceased? Absolutely! *Leg Med (Tokyo)*. 2020;47:101769. 10.1016/j.legalmed.2020.101769.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.