

## RELEVANT REVIEW

# One year of anatomy teaching and learning in the outbreak: Has the Covid-19 pandemic marked the end of a century-old practice? A systematic review

Veronica Papa<sup>1,2</sup>  | Elena Varotto<sup>2,3,4</sup> | Massimo Galli<sup>5,6</sup> | Mauro Vaccarezza<sup>7,8</sup>  | Francesco M. Galassi<sup>2,4,9</sup>

<sup>1</sup>Department of Motor Sciences and Wellness, School of Sciences, Engineering and Health, University of Naples "Parthenope", Naples, Italy

<sup>2</sup>Forensic Anthropology, Paleopathology and Bioarchaeology (FAPAB) Research Center, Avola, Italy

<sup>3</sup>Department of Humanities (DISUM), University of Catania, Catania, Italy

<sup>4</sup>Archaeology, College of Humanities, Arts and Social Sciences, Flinders University, Adelaide, South Australia, Australia

<sup>5</sup>Department of Biomedical and Clinical Sciences "Luigi Sacco", University of Milan, Milan, Italy

<sup>6</sup>III Division of Infectious Diseases, ASST Fatebenefratelli Sacco, Milano, Italy

<sup>7</sup>Curtin Medical School, Faculty of Health Sciences, Curtin University, Perth, Western Australia, Australia

<sup>8</sup>Curtin Health Innovation Research Institute (CHIRI), Faculty of Health Sciences, Curtin University, Perth, Western Australia, Australia

<sup>9</sup>Department of Biomedical and Neuromotor Sciences, University of Bologna, Bologna, Italy

## Correspondence

Dr. Veronica Papa, Department of Motor Sciences and Wellness, University of Naples "Parthenope", Via Medina 40, 80132, Napoli, Italy.  
Email: veronica.papa@uniparthenope.it

## Funding information

This research did not receive any specific grant from funding agencies in public, commercial, or not-for-profit sectors

## Abstract

At the end of 2019, the Covid-19 pandemic spread caused restrictions in business and social spheres. Higher education was also severely affected: universities and medical schools moved online to distance learning and laboratory facilities closed. Questions arise about the long-term effects of this pandemic on anatomical education. In this systematic review, the authors investigated whether or not anatomical educators were able to deliver anatomical knowledge during this pandemic. They also discuss the challenges that anatomical education has faced over the last year. The search strategy was conducted between July 2020 and July 2021. Two hundred and one records were identified, and a total of 79 studies were finally included. How best to deliver anatomy to students remains a moot point. In the last years, the advent of new technologies has raised the question of the possible overcoming of dissection as the main instrument in anatomical education. The Covid-19 pandemic further sharpened the debate. Remote learning enhanced the use of technologies other than cadaveric dissection to teach anatomy. Moreover, from the analyzed records it appears that both from students' perspective as well as teachers' there is a clear tear between those who endorse dissection and those who believe it could be easily overcome or at least integrated by virtual reality and online learning. The authors strongly believe that the best anatomy teaching practice requires the careful adaptation of resources and methods. Nevertheless, they support cadaveric dissection and hope that it will not be replaced entirely as a result of this pandemic.

## KEYWORDS

anatomy laboratories, body donation, cadaveric dissection, Covid-19, gross anatomy education, infectious diseases, medical education, pandemic

## INTRODUCTION

Anatomy has always been at the core of medical education, both in undergraduate and postgraduate teaching. Donor dissection and specimen-based dissection have been the primary methods of teaching human anatomy since the Middle Ages when Mondino de' Liuzzi (1275–1326) performed the first public dissection in Bologna (Papa et al., 2019b). Although the importance of teaching anatomy to both undergraduate and postgraduate students is undisputed, the best pedagogical approach to adopt remains an unresolved issue. Medical schools worldwide have recently reconsidered how to teach anatomy to their students, although dissection almost always remains part of the anatomical education for both undergraduate and postgraduate students (Papa & Vaccarezza, 2013; Ghosh, 2017; Vaccarezza, 2018; Papa et al., 2019a; Brassett et al., 2020). Unfortunately, medical schools have drastically reduced, if not cancelled, the hours devoted to dissection and gross anatomy classes (Drake et al., 2009; McBride & Drake, 2018; Pan et al., 2020; Rockarts et al., 2020). Moreover, the number of trained anatomists has also dramatically decreased, further impacting anatomy education in medical specialties. By learning from “silent teachers,” usually embalmed or fresh-frozen cadavers students have the opportunity to dissect organs evaluating the three-dimensionality (3D) of the human body as well as the anatomical variations (Salameh et al., 2020). As the “first patient” for clinicians in training, cadavers represent a crucial tool in teaching and research: many universities have dissection facilities and body donation programs and institutions usually use cadavers in the preclinical development of surgical instruments and procedures (Memon, 2018; Wilson et al., 2018; James et al., 2019). Dissection in anatomical education is much more than a helpful tool in learning the structure of tissues and organs: recent evidence demonstrated that the environment where anatomical knowledge is acquired, could help improving humanistic skills (nontraditional discipline-independent skills or NTDIS) (Cooper et al., 2010; Smith et al., 2015; Brunckhorst et al., 2017; Evans et al., 2018; Scrooby et al., 2019; Evans & Pawlina, 2020; Lachman & Pawlina, 2020; Evans, 2021; Roxburgh & Evans, 2021). Dissection led the students match knowledge with practice and patient care at an earlier stage of their career (Evans et al., 2018; Evans & Pawlina, 2020). Furthermore, the use of embalmed bodies in anatomical education provides students with situation awareness, decision making, communication, teamwork, leadership, managing stress and coping with fatigue that are crucial complement to healthcare professionals' technical skills and are required to ensure the delivery of safe and effective medical care (Fletcher et al., 2004; Yule et al., 2006; Flin et al., 2008; Pearson & McLafferty, 2011; Brunckhorns et al., 2017; Evans et al., 2018; Evans & Pawlina, 2020; McDaniel et al., 2021; Roxburgh & Evans, 2021). Therefore, body donation is a noble, generous and crucial act in the interest of safe clinical and surgical practice (McHanwell et al., 2008; Riederer et al., 2012; Riederer, 2016; Salameh et al., 2020).

Over the last decades, alternative and less costly teaching technologies (3D printing, the use of virtual reality, and dissection

software programs) have gradually replaced traditional anatomical education, with multiple ranges of study modules based on curricular integration (Nicholson et al., 2006; Wilson et al., 2018; Curlewis et al., 2021).

In December 2019, in the Hubei province of China, Wuhan was the center of an outbreak of pneumonia. A novel coronavirus (SARS-CoV-2) identified in January 2020 is the causative agent of this severe acute respiratory infection that spread worldwide, causing a global pandemic and becoming a primary global health concern (Wang et al., 2020). The World Health Organization (WHO) named the disease caused by this severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) Covid-19 on February 11 and subsequently labeled its global manifestation a pandemic a month later (Franchi, 2020).

In its weekly update, the WHO stated that in mid-July 2021, 190 million cases and 4 million deaths had been reported globally since beginning of the pandemic (WHO, 2021).

The governments worldwide imposed physical distancing regulations and restrictions to curb the Covid-19 pandemic spread, causing unexpected and rapid changes in anatomical teaching practices, and providing the opportunity to seriously reshape and modify future curriculum design and delivery for the anatomical sciences.

The Covid-19 pandemic further sharpened the debate on anatomical education. During the lockdown, the preclinical phase of medical curricula has successfully introduced the novel culture of “online home learning” using technological innovations such as distance learning, web resources, and virtual dissection software programs. Unfortunately, the lack of hands-on training in the preclinical years might have severe implications on the training of the current cohort of students (Gaur et al., 2020) in terms of technical as well as non-technical skills. However, in the face of adversity comes opportunity and this pandemic offered the unique chance to simultaneously assess the pros and cons of the two pedagogical approaches. Recently, several articles have described the impact of the Covid-19 pandemic on the teaching of human anatomy, but as far as the authors are concerned, the effects on cadaveric dissection as well as the use of other technological approaches with regard to future perspective have not yet been completely evaluated.

In this article, the authors systematically review the impact the Covid-19 pandemic has had on human anatomy education both from teaching and learning perspectives. Moreover, the authors discuss in a qualitative synthesis the strategies and challenges that anatomical education has faced over the last year answering and debating the following question: “were the anatomical educators able to deliver anatomical knowledge to students during the Covid-19 pandemic? At what price?”

## MATERIALS AND METHODS

A systematic review following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) method was

performed between July 2020 and July 2021 (Moher et al., 2015). Afterwards, the included records were screened and assessed to the qualitative synthesis. Moreover, when available non-narrative data were extracted and collected.

Since this study did not involve any type of human material (cells, tissues, organs, patients or other), the approval from the Ethical Committee was not required as well as the manuscript was not eligible for ethical review.

## Search strategy

The search strategy was conducted between July 2020 and July 2021. It was based on key search terms in PubMed (US National Library of Medicine, National Institutes of Health, Bethesda, MD), Biomed Central (BioMed Central Ltd., Springer Nature, London, UK), Scopus (Elsevier B.V., Amsterdam, the Netherlands), and Google Scholar (Google Inc., Mountain View, CA) search engines. The search strategy was designed by V.P. and validated by the two senior authors (M.V. and F.M.G.).

## Eligibility criteria

A literature search including the terms Covid-19 AND anatomical dissection OR anatomical education in the aforementioned search engines was carried out.

Inclusion criteria enclosed articles published in English and peer-reviewed journals and covered any type of study focusing on the Covid-19 pandemic and its effects on anatomical education or dissection. Keywords related to these terms were identified. Moreover, the authors searched the reference lists of articles identified through this search strategy and selected additional publications that they deemed relevant.

## Study selection and data extraction

Titles, abstracts, keywords, and full texts were reviewed by two authors (V.P. and E.V.). Eventually, conflicts between reviewers were discussed until a consensus was reached and one of the senior authors was involved if needed. A total of 201 records were initially identified. After duplicate removal, a total of 155 papers were further processed.

After title and keywords screening, a total of 79 studies were finally included (see Figure 1 for further details).

For all articles, abstracts, and keywords as well as the complete reference list were analyzed. Only items whose abstract unequivocally discusses the topic were included.

The records included in this study are listed in Table 1. All the authors agreed on the final number of studies included.

The PRISMA flow-chart (Moher et al., 2015) was utilized for the report of findings (Figure 1)

## Qualitative analysis

The qualitative synthesis of this study was based on the grounded theory methodology (Charmaz, 2005; Grossoehme, 2014). The authors extensively discussed the foundations of their query before formulating the research question: "were the anatomical educators able to deliver anatomical knowledge to students during the Covid-19 pandemic? At what price?"

The enrollment of records in the qualitative synthesis was made using the online Research Screener machine learning tool for systematic reviews (Chai et al., 2021; Research Screener, 2021). The sample in this qualitative analysis was represented by undergraduate and postgraduate medical students as well as medical educators who have learned and taught in anatomy/gross anatomy modules during the outbreak of the Covid-19 pandemic. The eligibility of the sample was limited from July 2020 to July 2021. Data were collected from written text represented by the included records.

Initially, the data set imported in Research Screener machine learning tool was represented by the 79 records originally included in this systematic review. Credibility and reliability were ensured by debriefing and triangulation.

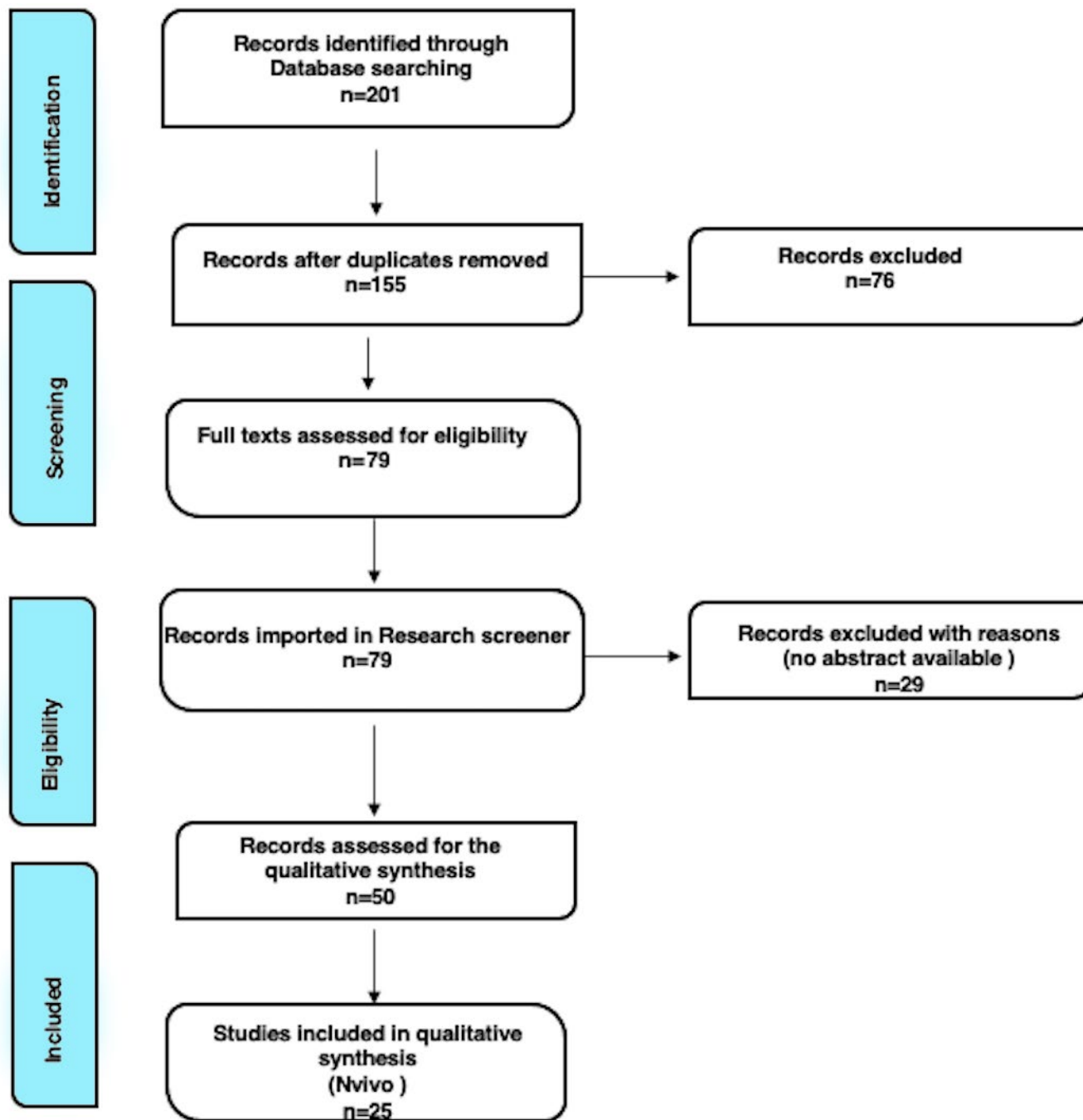
After extensive discussion between team members, six ( $n = 6$ ) seeds articles were identified (Naidoo et al., 2020; Pather et al., 2020; Banovac et al., 2021; Brassett et al., 2021; Iwanaga et al., 2021; Lemos et al., 2021). Twenty-nine ( $n = 29$ ) missing abstracts were automatically removed by the tool, therefore a final set of 50 abstracts was further screened. Two reviewers and an external expert who has full experience in qualitative research, independently flagged the abstract. Conflicts were discussed between reviewers and resolved. Eventually, one of the senior authors (M.V.) was involved if needed. Twenty-five records ( $n = 25$ ) were finally included in the qualitative synthesis. Afterwards, members of the team (V.P., E.V. and M.V.) independently coded and categorized the data into themes and subthemes, which were discussed on a regular basis.

Open codes were developed as well as themes and subthemes were generated using the trail version of NVivo qualitative data analysis software package (QSR International Pty, Ltd., Melbourne, VIC, Australia) (Bazeley, 2007; Wong, 2008). These themes were reviewed by all authors to ensure they were fully consistent with the research question. Any further discrepancy was discussed in order to minimize bias.

## Non-narrative data collection

When available, the main features of the included records were extracted, categorized and imported to Excel (Microsoft Corp., Redmond, WA) for further evaluation.

The included records were analyzed in term of non-narrative data including the type of publication (letter to the editor, original research, review etc.); country of study (identified from the affiliation of the corresponding author); recruitment of students and/or university staff, and eventually their personal details. Further analysis of the data followed.



**FIGURE 1** Flowchart of the reporting items for the systematic review adapted from the preferred reporting items for systematic reviews (PRISMA) statement (Moher et al., 2015). Two hundred and one records were initially identified; 79 were included and further processed using open online Research Screener machine learning tool (Research Screener, 2021). Of those, 25 were assessed for the qualitative synthesis using NVivo qualitative data analysis software (QSR International Pty, Ltd., Melbourne, VIC, Australia)

## RESULTS

### Qualitative synthesis

Safety measures, physical distances and regulations imposed by the government worldwide due to the outbreak of the Covid-19 pandemic caused sudden and deep changes to anatomical education, forcing lecturers and students to rapidly switch their approach from

in person to online learning. Although distance learning cannot be considered a novelty and it has been used successfully in the past, the transition from face-to-face to remote learning had a tremendous impact both on anatomical educators and medical students, and represented a challenge and an opportunity to rethink the future of anatomical education.

Two main themes were generated from the results: the first related to the different modalities in which educators and students faced the

TABLE 1 List of the records included in the systematic review

Study details	Title	Type of study	Key words	Country	Students and/or teachers enrollment
Alsafi et al. (2020) Int J Surg	The coronavirus (Covid-19) pandemic: Adaptations in medical education	Letter	Not available	UK	Not recruited
Alsharif et al. (2020) Med Sci	Proposed Guidelines for the "New Norm" of Anatomy Teaching	Perspective	Covid-19; anatomy teaching; Infection control measures; anatomy laboratories; dissection; prosected cadavers; plastinated specimens; plastination; plastic models; virtual cadavers	Saudi Arabia	Not recruited
Banovac et al. (2021) Croat Med J	The anatomy lesson of the SARS-CoV-2 pandemic: irreplaceable tradition (cadaver work) and new didactics of digital technology	OR	Not available	Croatia	340 first-year medical students. Demographic information of participants not included
Barash et al. (2021) Anat Sci Educ	Educating Future Doctors in Covid-19 Times: Anatomists Lead the Way!	Letter	Not available	Israel	Not recruited
Böckers et al. (2021) Ann Anat	Teaching anatomy under Covid-19 conditions at German universities: recommendations of the teaching commission of the anatomical society	Viewpoint	Anatomy teaching; Covid-19; pandemic; remote learning; face-to face-learning	Germany	Not recruited
Bond and Franchi (2021) Med Educ Online	Resuming cadaver dissection during a pandemic	Letter	Cadaver dissection; anatomical education; medical students; Covid-19; pandemic	UK	Not recruited
Brassett et al. (2021) Eur J Anat	Maintaining cadaveric dissection in the Covid era: new perspectives in anatomy teaching and medical education	OR	Not available	UK	Not recruited
Brassett et al. (2020) J Anat	Covid-19 and anatomy: stimulus and initial response	Review article	Anatomy; body donation; coronavirus; Covid-19; education	UK	Not recruited
Bymes et al. (2021) Clin Anat	Communication, collaboration and contagion: "Virtualisation" of anatomy during Covid-19	Review	Anatomy; Covid-19 in lieu of medicine; embryology; medical education; medicine; surgery	ROI	Not recruited
Cheng et al. (2021a) Anat Sci Educ	Gross anatomy education in China during the Covid-19 pandemic: A national survey	Descriptive article	Covid-19 pandemic; active learning; body donation; gross anatomy education; medical education; online assessment; online teaching; practical sessions; theoretical sessions	China	Faculty members of 77 medical schools. Number of participants and demographic information not included

(Continues)

TABLE 1 (Continued)

Study details	Title	Type of study	Key words	Country	Students and/or teachers enrollment
Cheng et al. (2021b) Med Sci Educ	Developing a Hybrid Four-Prong Approach to Anatomical Education During the Covid-19 Pandemic	Monograph	Anatomy; Covid-19; live-streamed reviews; undergraduate medical education; laboratory dissection	Canada	Faculty members and medical students at Schulich. Number of participants and demographic information not included
Chytas et al. (2020) Anat Sci Educ	Decline of cadaveric dissection in anatomy education during the Covid-19 pandemic: Can it affect future surgeons' competency?	Letter	Gross anatomy education; medical education; undergraduate education; cadaveric dissection; surgery; surgical competency; surgical skills; Covid-19	Cyprus	Not recruited
Consorti et al. (2021) Med Teach	A SWOT analysis of Italian medical curricular adaptations to the Covid-19 pandemic: A nationwide survey of medical school leaders	OR	International medical education; change; undergraduate; curriculum; evaluation	Italy	60 heads of medical schools. Demographic information not included
Cortese and Frascio (2021) Anat Sci Educ	New Settings in Anatomy and Surgery Teaching During the Covid-19 Pandemic	Letter	Not available	Italy	Not recruited
Cuschieri and Calleja Agius (2020) Anat Sci Educ	Spotlight on the shift to remote anatomical teaching during Covid-19 pandemic: perspectives and experiences from the University of Malta	OR	Coronavirus; Covid-19; medical education; medical students; anxiety disorders	Malta	172 preclinical medical students. 58 males; 114 females
Das and AlMushaiqri (2021) Anat Sci Educ	Anatomy Online Teaching During Covid-19 Pandemic: The Need for Responsive Anatomy Learning Ecosystem	Letter	Not available	Saudi Arabia-Sultanate of Oman	Not recruited
Dost et al. (2020) BMJ Open	Perceptions of medical students toward online teaching during the Covid-19 pandemic: a national cross-sectional survey of 2721 UK medical students	OR	Not available	UK	2721 medical students. 858 males; 1852 females; 11 others
Dulohery et al. (2021) Clin Anat	Emerging from emergency pandemic pedagogy: A survey of anatomical educators in the United Kingdom and Ireland	Not available	Assessment; Covid-19; distance teaching; gross anatomy; medical education; remote working	UK	24 anatomists across 15 universities in the UK (11) and ROI (4)
Elzainy et al. (2020) J Taibah Univ Med Sci	Experience of e-learning and online assessment during the Covid-19 pandemic at the College of Medicine, Qassim University	OR	Covid-19; e-learning; online assessment; online PBL; pandemic; virtual classroom	Saudi Arabia	674 medical students. 425 undergraduates; 249 clinical phase. 407 males; female 267; and 120 instructors

TABLE 1 (Continued)

Study details	Title	Type of study	Key words	Country	Students and/or teachers enrollment
Evans and Pawlina (2021) Anat Sci Educ	Effects of Covid-19: The Need to Assess the Real Value of Anatomy Education	Editorial	Not available	USA	Not recruited
Evans et al. (2020) Anat Sci Educ	Going virtual to support anatomical education: a STOP GAP in the midst of the Covid19 Pandemic	Editorial	Not available	USA	Not recruited
Flynn et al. (2021) Clin Anat	Delivering online alternatives to the anatomy laboratory: early experience during the Covid-19 pandemic	OR	Anatomy; medical education; medicine; surgery; embryology; Covid-19; pandemic; education; online learning; distance learning; video conferencing; collaborative learning; technology enhanced learning; 3D modelling; innovation	UK	Medical students. Number of participants and demographic information not included
Franchi (2020) Anat Sci Educ	The impact of the Covid-19 pandemic on current anatomy education and future careers: a student's perspective	Letter	Not available	UK	Not recruited
Gaur et al. (2020) SN Compr Clin Med	Challenges and opportunities of preclinical medical education: Covid-19 crisis and beyond	Review	Covid-19 pandemic; preclinical medical education; online learning; remote learning; challenges; opportunities	Barbados	Not recruited
Gupta and Pandey (2020) J Lumbini Med Coll	Disruption of anatomy dissection practical in Covid-19 pandemic : challenges, problems and solutions	Perspective	Not available	India	Not recruited
Harmon et al. (2021) Anat Sci Educ	An Analysis of Anatomy Education Before and During Covid-19: May–August 2020	Editorial	Gross anatomy education; medical education; coronavirus; Covid-19; virtual anatomy; online anatomy; remote teaching; laboratory; lecture; integrated curriculum; stand-alone courses	USA	67 anatomy educators. Demographic information not included
Iwanaga et al. (2021) Clin Anat	A review of anatomy education during and after the Covid-19 pandemic: Revisiting traditional and modern methods to achieve future innovation	Viewpoint	Medical education; Covid-19; novel coronavirus; SARS-CoV-2; virtual; technology; cadaver; dissection; anatomy education; teaching	USA	Not recruited
Jones. (2020) Anat Sci Educ	Ethical Responses to the Covid-19 Pandemic: Implications for the Ethos and Practice of Anatomy as a Health Science Discipline	OR	Gross anatomy education; ethics; Covid-19 pandemic; online delivery; body bequests; ethical framework	New Zealand	Not recruited
Jones (2021) Anat Sci Educ	Anatomy in a post-Covid-19 world: tracing a new trajectory	Viewpoint	Gross anatomy education; medical education; Covid-19; online teaching; online resources; research; workload; virtual anatomy museums	New Zealand	Not recruited
Kanneganti et al. (2020) Postgrad Med J	Continuing medical education during a pandemic: an academic institution's experience. Postgrad Med J 9.6:384–386	Not available	Not available	Singapore	Not recruited

(Continues)

TABLE 1 (Continued)

Study details	Title	Type of study	Key words	Country	Students and/or teachers enrollment
Karkera (2021) Int J Res Med Sci	Impact of Covid-19 on the future of cadaveric dissection and anatomy teaching	Review	Dissection; prosected; plastinated; anatomage	USA	Not recruited
Keet et al. (2021) Med Sci Educ	Development of a Virtual Journal Club in Anatomy: a Responsive Pandemic Pedagogy	OR	Virtual journal club; anatomical education; Covid-19; pandemic; online learning	South Africa	Members of the Clinical Anatomy journal club. Number of participants and demographic information not included
Khalil et al. (2020) BMC Med Educ	The sudden transition to synchronized online learning during the Covid-19 pandemic in Saudi Arabia: a qualitative study exploring medical students' perspectives	OR	Sudden transition; online learning; Covid-19 pandemic; Saudi Arabia; qualitative study; medical students; perspective	Saudi Arabia	60 medical students. 24 males; 36 females
Korkmaz and Ilke Ali Gürses (2020) Anatomy	Initial effects of Covid-19 pandemic on graduate anatomy education in Turkey	OR	Anatomy education; Covid-19; graduate education; Turkey	Turkey	75 medical students. 19 males; 51 females
Lee et al. (2021) Eur Rev Med Pharmacol Sci	Changes in undergraduate medical education due to Covid-19: a systematic review	Review	Covid-19; systematic review; undergraduate medical education	Korea	Not recruited
Lemos et al. (2021) Ann Anat	Human anatomy education and management of anatomic specimens during and after Covid-19 pandemic: ethical, legal and biosafety aspects	Short communication	Anatomy education; biosafety; SARS-CoV-2; Covid-19	Brazil	Not recruited
Loda et al. (2020) PLoS ONE	Medical education in times of Covid-19: German students' expectations—A cross-sectional study	OR	Not available	Germany	679 medical students. 92 males; 279 females; 1 other
Longhurst et al. (2020) Anat Sci Educ	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	OR	Gross anatomy education; undergraduate education; medical education; distance learning; Covid-19; anatomy; pedagogy; assessment; online education	UK	14 universities in the UK and ROI (12+2). Number of participants and demographic information not included
Manzanares-Céspedes et al. (2021) Anat Sci Educ	Body donation, teaching and research in dissection rooms in Spain in times of Covid-19	Report	Gross anatomy education; medical education; undergraduate education; Covid-19; dissection; translational research	Spain	Not recruited
Mateen and Kan (2021) Clin Teach	Education during Covid-19: Ready, headset, go!	Insight	Not available	UK	Not recruited
McCumber et al. (2021) Clin Anat	The state of anatomical donation programs amidst the SARS-CoV-2 (Covid-19) pandemic	OR	Anatomy education; cadaver; coronavirus Covid-19; deeded human body donor SARS-CoV-2	USA	Not recruited



TABLE 1 (Continued)

Study details	Title	Type of study	Key words	Country	Students and/or teachers enrollment
Mehdar (2020) Univ J of Educ Res	Students' Attitudes as Regard to Distance Learning of Anatomy Courses throughout Covid-19 Pandemic Lockdown Period among Medicine and Paramedical Faculties of Najran University; Saudi Arabia	Not available	Anatomy; distance learning; Covid-19; pandemic; medical; blackboard	Saudi Arabia	70 medical and paramedical students. Demographic informations not included
Moszkowicz et al. (2020) Clin Anat	Daily medical education for confined students during coronavirus disease 2019 pandemic: A simple videoconference solution	Viewpoint	Anatomical learning; anatomy; Covid-19 pandemic; medical education	France	Not recruited
Muñoz-Leija et al. (2020) Eur J Anat	Modifications to the delivery of a gross anatomy course during the Covid-19 pandemic at a Mexican medical school	OR	Medical education; Covid-19; human anatomy; Coronavirus—near peers; academic staff; students	Mexico	Not recruited
Naglik and Ravindran (2020) Int J Surg	A commentary on "The coronavirus (Covid-19) pandemic: Adaptations in medical education"	Viewpoint	Medical education; medical students; Covid-19 pandemic; medical teaching; patient safety; online learning; e-learning; video platforms general medical council	UK	Not recruited
Naidoo et al. (2020) J Med Internet Educ Med Educ	Confronting the challenges of anatomy education in a competency-based medical curriculum during normal and unprecedented times (Covid-19 pandemic): pedagogical framework development and implementation	OR	Undergraduate medical education; anatomy education; Gagne's nine-events of instruction; Peyton's four-step approach; Mento's 12-step change management model; Bourdieu's Theory of Practice; social-media application interactome; Covid-19	Dubai	Not recruited
Naidoo (2021b) SN Compr Clin Med	Could Covid-19 Trigger a Rebirth in Anatomy Education? A Glimpse of Anatomists' Responses to Pandemics of the Past and Present	Not available	Anatomy education; cadaveric dissection; Covid-19; future; pandemics	Dubai	Not recruited
Okafor and Chia (2020) Anat Sci Educ	Covid-19: emerging considerations for body sourcing and handling a perspective view from Nigeria	Review	Gross anatomy education; medical education; body donation; body handling; occupational safety; coronavirus; Covid-19; SARS-CoV-2; ethics; Africa	Nigeria	Not recruited
Onigbinde et al. (2021) Morphologie	The place of cadaveric dissection in post-Covid-19 anatomy education	Review	Cadaveric dissection; Covid-19; cadavers; anatomy education; pandemic	Nigeria	Not recruited
Onigbinde (2021) Morphologie	Covid-19 pandemic era: How risky is the continuous usage of cadavers for teaching and research?	Editorial	Not available	Nigeria	Not recruited
Ooi and Ooi (2020) Med Educ Online	Impact of SARS-CoV-2 virus pandemic on the future of cadaveric dissection anatomical teaching	Letter	Undergraduate; anatomy teaching; cadaver; dissection; Coronavirus	UK	Not recruited

(Continues)

TABLE 1 (Continued)

Study details	Title	Type of study	Key words	Country	Students and/or teachers enrollment
Oyeniran (2020) <i>Ulutas Med J</i>	Sourcing and Availability of Cadavers for Anatomical Dissection Amid Covid-19 Pandemic: Safety Challenges and Possible Solutions	Review	Anatomical dissection; Covid-19; Cadavers; Medical education; Pandemic	Nigeria	Not recruited
Pather et al. (2020) <i>Anat Sci Educ</i>	Forced disruption of anatomy education in Australia and New Zealand: an acute response to the Covid-19 pandemic	Report	Gross anatomy education; medical education; Covid-19 pandemic; Australia; New Zealand; online delivery; student well-being; reflective practices; workload; online practical anatomy; active learning; remote learning	Australia	Anatomists from the Australia and New Zealand Association of Clinical Anatomists (ANZACA). Number of participants and demographic information not included
Patra et al. (2021) <i>Anat Sci Educ</i>	Adverse impact of Covid-19 on anatomical sciences teachers of India and proposed ways to handle this predicament	Letter	Gross anatomy education; medical education; digital anatomy; teaching faculty; Covid-19; India	India	Not recruited
Patra et al. (2021) <i>Anat Sci Int</i>	Covid-19 reflection/experience on teaching-learning and assessment: story of anatomy teachers in India	Letter	Not available	India	Not recruited
Pearson (2020) <i>Acad Med</i>	Anatomy: Beyond the Covid-19 Pandemic	Letter	Not available	USA	Not recruited
Pushpa and Ravi (2020) <i>Natl J Clin Anat</i>	Does the Corpse teach the living?—Anatomy in the era of Covid-19	Editorial	Not available	India	Not recruited
Rajasekhar and Dinesh Kumar (2021) <i>SN Compr Clin Med</i>	The cadaver conundrum: Sourcing and anatomical embalming of human dead bodies by medical schools during and after Covid-19 pandemic: Review and recommendations	Not available	Body donation program; Cadaver; Covid-19 pandemic; embalming; medical education	India	Not recruited
Ravi (2020) <i>Anat Sci Educ</i>	Dead body management in times of Covid-19 and its potential impact on the availability of cadavers for medical education in India	Letter	Not available	India	Not recruited
Raymond-Hayling (2020) <i>Med Educ Online</i>	What lies in the year ahead for medical education? A medical student's perspective during the Covid-19 pandemic	Letter	Covid-19; clinical education; online teaching; physical examination; social distancing	UK	Not recruited
Remtulla (2020) <i>JMIR Med Educ</i>	The Present and Future Applications of Technology in Adapting Medical Education Amidst the Covid-19 Pandemic	Viewpoint	Medical education; technology; coronavirus; medical students; Covid-19; pandemic; online lecture; virtual reality	UK	Not recruited
Romero-Reveron (2020) <i>Int J Med Surg Sci</i>	Human anatomical dissection takes a compulsory break during Covid-19 pandemic	Short communication	Human anatomical dissection; medical studies during Covid-19 pandemic; generation Z	Venezuela	Not recruited

TABLE 1 (Continued)

Study details	Title	Type of study	Key words	Country	Students and/or teachers enrollment
Ross et al. (2021) Clin Anat	Teaching anatomy with dissection in the time of Covid-19 is essential and possible	Letter	Not available	USA	Not recruited
Roy et al. (2020) J Clin Diagn Res	Faculties Perception on Anatomy Teaching and Assessment in Lockdown and Post-lockdown New Normal Phase	OR	Coronavirus disease; Objective structured practical examination; Online education	India	163 anatomy schools in the Anatomical Society of India. Number of participants and demographic information not included
Santurro et al. (2020) Forensic Sci Med Pathol	A technical report from the Italian SARS-CoV-2 outbreak. Postmortem sampling and autopsy investigation in cases of suspected or probable Covid-19	Report	SARS-CoV-2; Covid-19; Virological diagnosis; Autopsy investigation; Postmortem diagnosis	Italy	Not recruited
Saverino (2021) Clin Anat	Teaching Anatomy at the Time of Covid-19	Letter	Not available	USA	Not recruited
Shahrvini et al. (2021) BMC Med Educ	Pre-clinical remote undergraduate medical education during the Covid-19 pandemic: a survey study	OR	Covid-19; medical education; Pre-clinical; Distance learning; Remote learning	India	104 medical students. Demographic information not included
Silali (2020) Int J Publ Health Epidemiol Res	Health Determinants of Safe Infection Prevention Control of Covid-19 Deaths to enable safe Disposal and Cadavers Dissection as Distinct Educational Tools in Western Kenya	OR	Airborne disease; Covid-19; fresh embalment fluid; global health; population health; health promotion; primary prevention	India	Not recruited
Singal et al. (2020) Morphologie	Cadaverless anatomy: darkness in the times of pandemic	Editorial	Anatomy education; Body donation; Covid-19; Pandemic; virtual classes	Barbados	Not recruited
Singal et al. (2021) Surg Radiol Anat	Anatomy education of medical and dental students during Covid-19 pandemic: a reality check	OR	Anatomy education; Covid-19; dissection course; students; virtual classes	India	80 medical and dental students. Demographic information not included
Singh et al. (2020) Adv Hum Biol	Teaching anatomy and dissection in an era of social distancing and remote learning	Review	Anatomy teaching; challenges; Covid-19; dissection; face-to-face; online teaching; opportunities; remote teaching	USA	Not recruited
Singh and Pakhiddey (2020) J Anat Soc India	Acceptance of donor bodies and their embalming during Covid-19 period: A challenge to anatomists	Editorial	Not available	Germany	Not recruited

(Continues)

TABLE 1 (Continued)

Study details	Title	Type of study	Key words	Country	Students and/or teachers enrollment
Skok et al. (2021) Pathol Res Pract	Covid-19 autopsies: Procedure, technical aspects and cause of fatal course. Experiences from a single-center	Short communication	Covid-19; SARS-CoV-2; post mortem; autopsy; pneumonia; cause of death	Singapore	Not recruited
Smith and Pawlina (2021) Anat Sci Educ	A journey like no other: anatomy 2020!	Editorial	Not available	Turkey	Not recruited
Sperhake (2020) Leg Med (Tokyo)	Autopsies of Covid-19 deceased? Absolutely!	Not available	Covid-19 SARS-CoV-2 Pandemic Autopsy Post mortem	USA	Not recruited
Srinivasan (2020) Anat Sci Educ	Medical Students' Perceptions and an Anatomy Teacher's Personal Experience Using an e-Learning Platform for Tutorials During the Covid-19 Crisis	Letter	Not available	USA	16 medical students. Demographic information not included
Tekiner et al. (2020) HCA Healthc J Med	Covid-19 Era Requires Urgent Integration of Virtual Reality Simulations in Medical Education	Not available	Covid-19; medical education; virtual reality; simulation-based educations; graduate medical education; educational virtual reality; coronavirus infections; SARS-CoV-2; simulation training	USA	Not recruited
Theoret and Ming (2020) Med Educ	Our education, our concerns: The impact on medical student education of Covid-19	Viewpoint	Not available	UK	Not recruited
Thom et al. (2021) Anat Sci Educ	Is remote near-peer anatomy teaching an effective teaching strategy? Lessons learned from the transition to online learning	Report	Gross Anatomy education; Undergraduate Education; Medical Education; Preclinical Courses; Near-Peer Teaching; Online Learning; Covid-19	Korea	2022-2024 anatomy classes. 552 students. Demographic information of participants not included
Tucker and Anderson (2021) Anat Sci Educ	Dissection experience and performance on a human gross anatomy written examination: lessons learned during the Covid-19 pandemic	Letter	Not available	USA	128 medical students. Demographic information not included
Wilcha (2020) JMIR Med Educ	Effectiveness of Virtual Medical Teaching During the Covid-19 Crisis: Systematic Review	Review	Virtual teaching; medical student; medical education; Covid-19; review; virus; pandemic; quarantine	UK	Not recruited
Yoo et al. (2021) J Korean Med Sci	Adaptations in Anatomy Education during Covid-19	OR	Anatomy education; Covid-19; blended learning; self-directed learning	Saudi Arabia	212 medical students. Demographic information not included

Note: The table details the main features of the included records: authors, type of the study, keywords, country and eventually the recruitment of students and/or staff. The corresponding author's affiliation has been considered as the article's nationality. When available, the personal details of the enrolled participants have been included.

Abbreviations: ANZACA, Australia and New Zealand Association of Clinical Anatomists; COVID, coronavirus infectious disease; letter, letter to the editor; OR, original research; PBL, problem-based learning; perspective, perspective article; review, review article; ROI, Republic of Ireland; SC, short communication; SWOT, strength, weakness, opportunity, threat; UK, United Kingdom; USA, United States of America.

transition from in person to remote learning and the second focused on the impact that the Covid-19 pandemic had on cadaveric dissection.

Subthemes covered numerous aspects including stress factors related to students' anxiety or concerns on their future competences as well as educators' concern about their increased workload. Also, subthemes were identified with regard to the impact that the closure of dissection facilities had on students in terms of lack of hands-on training, surgical competency, NTIDS, as well as the future of body donation programs (Figure 2).

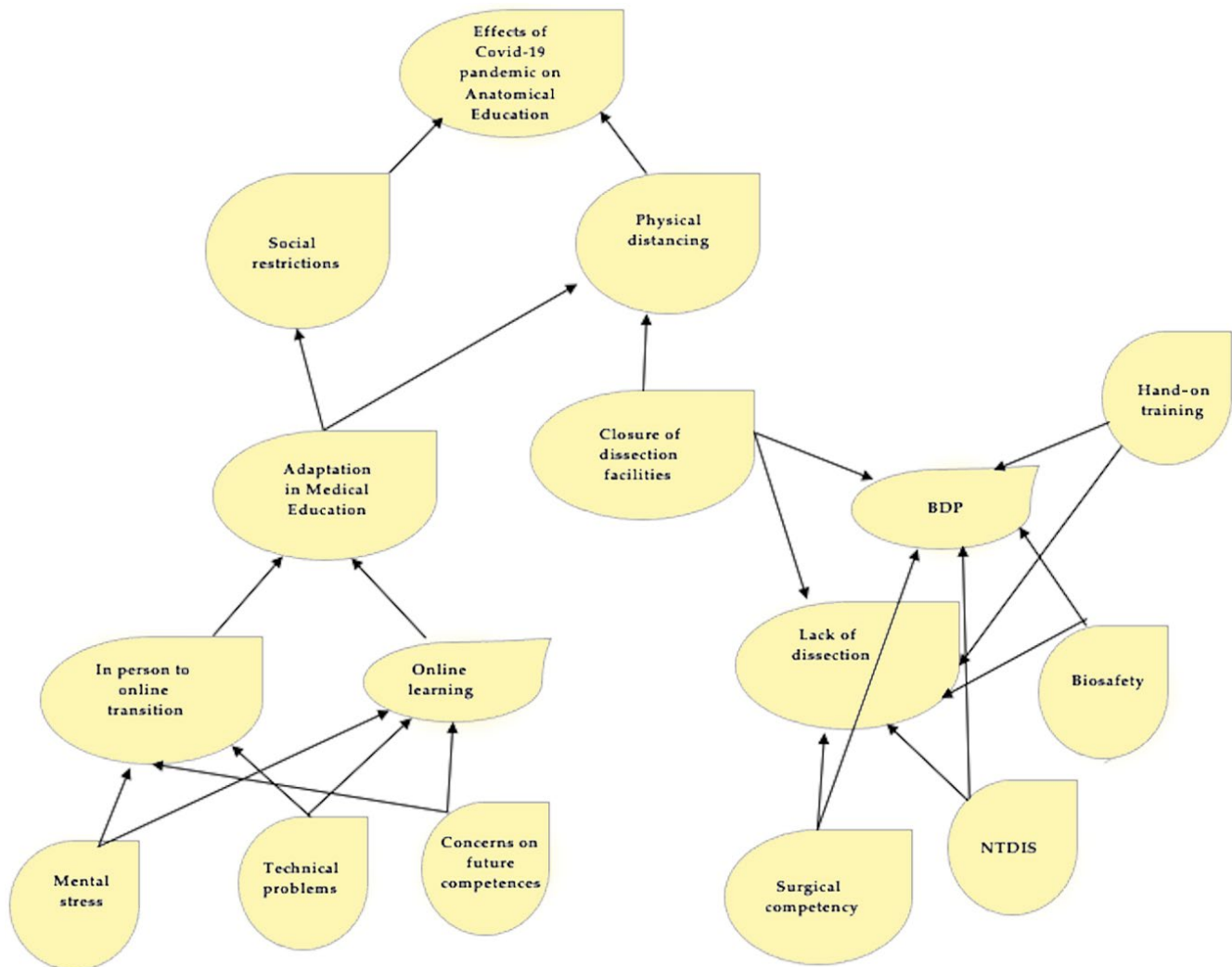
### Features of the included records

Although this systematic review was not aimed to a statistical analysis and a quantitative synthesis, non-narrative data were extracted from the included records.

These non-narrative data included the type of paper, the geographical distribution as well as the main features of the respondents to the surveys.

Although no statistical analysis of the collected non-narrative data has been performed, they provide a preliminary overview of the data currently available.

Seventy-nine ( $n = 79$ ) records were included in this systematic review. Of those, 7 records were classified as viewpoints/commentaries ( $n = 7$ ; 8.9%), 17 ( $n = 17$ ; 21.52%) as letters to the editor, 9 ( $n = 9$ ; 11.4%) as reviews, 3 ( $n = 3$ ; 3.8%) as perspectives, 2 ( $n = 2$ ; 2.5%) as short communication, 4 ( $n = 4$ ; 5.1%) as report, 22 ( $n = 22$ ; 27.8%) as original research, and 7 ( $n = 7$ ; 8.9%) as editorials. One article was classified as monograph ( $n = 1$ ; 1.26%). Seven article types were not indicated ( $n = 7$ ; 8.9%) (Table 1; Figure S3 in Supporting Information). The majority of the records was from the United Kingdom ( $n = 15$ ; 18.99%), followed by the United States of America ( $n = 13$ ; 16.46%)



**FIGURE 2** Nodes diagrams based on NVivo qualitative data analysis software output (QSR International Pty, Ltd., Melbourne, VIC, Australia). The larger clouds have been used to identify themes, the smaller to define subthemes. BDP, body donation program; NTIDS, nontraditional discipline-independent skills

and India ( $n = 10$ ; 12.66%) (Table 1; see Figures S3 and S4 in the Supporting Information for further details).

Moreover, 24 records out of 79 reported the recruitment of students ( $n = 22$ ; 27.84%) and/or teachers ( $n = 9$ ; 11.39%) (Table 1).

Only two studies enrolled other than medical students: Mehdar (2020) recruited medical and paramedical students whereas Singal et al. (2021) included both medical and dental students. Fifteen studies did not report the number of the enrolled participants, their demographic information or both. If reported, these data were further analyzed (see Table 1 for further details). Overall, 5883 students were enrolled in the analyzed studies. Moreover, most of the enrolled students were from the United Kingdom ( $n = 2721$ ; 46.25%), followed by Saudi Arabia ( $n = 804$ ; 13.67%) and the United States ( $n = 784$ ; 13.33%).

## DISCUSSION

“Were the anatomical educators able to deliver anatomical knowledge to students during the Covid-19 pandemic? At what price?” Undoubtedly, the answer to this question is: “Yes, they were. Unfortunately, the price to be paid was the interruption of dissection activities, the lack on hand-on training and the lost chance of developing NTIDS”.

Generally, anatomists have succeeded in adapting their teaching to online delivery and were able to experience new pedagogical approaches and to improve their digital knowledge and skills significantly. Nevertheless, anatomical educators preferred the face-to-face contact and were worried about the lack of educational hands-on activities, teamwork, and exposure to cadaveric material eventually resulting in a poorer 3D understanding (Böckers et al., 2021; Cheng et al., 2021a). Academic staff also referred the lack of feedback from instructor-to-learner and learner-to-learner and its increased workload especially for female academic staff (Cheng et al., 2021b; Dulohery et al., 2021; Jones 2021; Thom et al., 2021).

Moreover, online teaching was well accepted by students who generally wish to be able to continue to use online resources in the future. Nevertheless, they also referred anxiety symptoms as well as worries on their mental and emotional wellbeing. Online teaching was reported to be time saving and able to enhance students' performances as well as their ability to be focused on preparing for clinical placements. Although family distractions, technical problems, lack of motivation, difficulty concentrating were often identified as treats, only two studies clearly reported that students felt that remote learning had negatively affected the quality of instruction as well as the interaction between peers and educators (Mehdar et al., 2020; Shahrvini et al., 2021). Also, it was generally felt that digital visual resources were not fully adequate to replace for the cadaveric dissection. The majority of the students agreed that they missed the dissection courses and declared to feel less confident in the topics completed without dissections, models, microscopic slides and other modalities. Generally, students were told to be more willing to transfer lectures, seminars and other similar activities to online resources

rather than practice and dissection hours. Although few data on the learning outcomes of the educational approach used during this pandemic are currently available, educators and students' feelings regarding the online learning are consistent with idea that dissection and face-to-face learning could not be completely overcome in the future. The use of digital technologies appears to be indispensable for the transformative change in post-Covid anatomical education, but teachers and students agree that dissection in anatomical education is an extremely crucial tool in educational opportunity and benefit for institutions to indefinitely curtail its use as an anatomical pedagogy.

Indeed, how medical educators taught anatomy changed throughout the centuries, ranging from dissection to virtual reality and leading to a serious reshape of anatomy education to these days (Evans, 2021). The useful and substantial technical improvements (online resources, software programs, 3D printing and others) have modified the way anatomy is delivered (Kurul et al., 2020; Chytas et al., 2022; Gloy et al., 2022). Technical advances now allow anatomical education to be delivered without cadavers, and most medical schools worldwide have reduced or ceased the use of cadaver dissection (Periya, 2017; McBride & Drake, 2018; Goh & Sandars, 2020).

Recently, the Covid-19 pandemic forced teachers and students to stay safe at home and learning human anatomy online. During this pandemic human anatomical dissection takes a compulsory break like most human activities (Romero-Reveron, 2020). Therefore, the role of technological innovations in anatomical education was boosted, and the use of remote learning was implemented and further evaluated (Tekiner et al., 2020; Mateen & Kan, 2021).

The price to be paid was the compulsory break that cadaveric dissection had during the pandemic and the inevitable consequences that this interruption has entailed and will entail in the future. In fact, even though the online/distance learning approach does not represent a novelty in the context of anatomy education (Evans et al., 2020), the in person to online transition was tough and challenging for academic staff as well as for students.

Approximately 107 countries rapidly implemented their educational institutions' closures globally, impacting over 1.38 billion learners (Roy et al., 2020; Smith & Pawlina, 2021). Also, there was a 68% decrease in in-person lectures and a 50% reduction in cadaver materials during the initial emergence of the Covid-19 pandemic (Harmon et al., 2021). Anatomy Departments closed their facilities with different timings and moved all the teaching activities online. Also, body donation programs ceased except for donors whose bodies had already been processed.

Nevertheless, Longhurst and colleagues identified positive consequences, such as the potential to create new resources and foster academic collaborations that somehow balanced the adverse effects (time pressure, changes to assessment, and implications in students' engagements and relationships).

Anatomy was “virtualized” as “novel” methods of deliver anatomical knowledge were developed (Gupta & Pandey 2020; Moszkowicz et al., 2020; Byrnes et al., 2021; Cheng et al., 2021b; Flynn et al., 2021; Keet et al., 2021; Patra et al., 2021b).

Unfortunately, few articles on the short-term as well as long-term effect on the efficacy of these new methods to deliver anatomy education have been published so far.

Only two of the included records (Thom et al., 2021; Yoo et al., 2021) examined the learning outcomes of a this newly adopted Covid-19-due anatomy educational approach. Therefore, it is now premature trying to assess the long-term effect of this pandemic in term of education, technical skill, humanities (NTDIS). Hopefully, a blended/mixed learning curriculum able to give students both the opportunity for online interaction as well as in-person dissection classes able to develop technical as well as non-technical skills would be the most suitable solution for the upcoming years (Alsharif et al., 2020; Karkera, 2021). It is also clear that the online replacement of anatomy teaching will create some inevitable gaps in the content, knowledge, and practical application. It will probably affect the students' enrolment in courses with an anatomical component over the coming years.

Moreover, since Covid-19 might not disappear for a long time, it is likely that body donations are going to dwindle even more (Singal et al., 2020). Therefore, a "cadaver less" era might be on the brink (Brassett et al., 2020; Oyeniran, 2020; Pushpa & Ravi, 2020; Singal et al., 2020; Singh & Pakhiddey, 2020; Lemos et al., 2021; Naidoo et al., 2021a, b; Skok et al., 2021).

To date, although no evidence has been reported with regard to SARS-CoV-2 infection from cadavers (Bazaid et al., 2020; Ravi, 2020; Ren et al., 2020; Sperhake, 2020; Ross et al., 2021; Onigbinde, 2021), it is not entirely unlikely. SARS-CoV-2 has been reported in bodily fluids like sputum, feces, and eye fluid but less is known about the virus's survival rates outside the human host or after host death (Dijkhuizen et al., 2020; Silali, 2020; Santurro et al., 2020).

Therefore, it's clear now, more than ever how the rules and procedures regarding anatomic specimens, eventually positive or suspect for Covid-19, must be re-thought and implemented to guarantee the proper and safe management of the sample and all users (Osborn et al., 2020; Manzanares-Céspedes et al., 2021; Rajasekhar & Dinesh, 2021).

It is also worth mentioning that embalmed cadavers have the advantage over fresh-frozen ones of carrying minimal risk of infection and being suitable for prolonged use (Brenner, 2014; Balta et al., 2015a, b). Moreover, the type of embalming fluid and the length of storage might influence the virus's viability in the donated body and in some way mitigate the risk of infection (Balta et al., 2015a). No evidence is available so far, and further studies need to be performed before placing students and staff at risk.

After the first epidemic wave, only some universities have restarted their body donation programs, despite the uncertainties linked to the potential of renewed lockdowns or concerns around the ability to guarantee that donor bodies are negative for Covid-19 (Bond & Franchi, 2021; Manzanares-Céspedes et al., 2021). Distancing and safety protocols has been implemented demonstrating that cadaveric dissection in the Covid-19 era is essential and possible (Barash et al., 2021; Tucker & Anderson, 2021).

Moreover, recent evidence, presented at the Anatomical Society summer meeting virtually held in Glasgow in July 2021, clearly demonstrated that, although students feel more comfortable with these blended activities and found this method effective, they missed the dissection room and want to be back to hands-on training.

Surprisingly, research in gross anatomy did not cease during this pandemic year. A novel cadaveric embalming technique for enhancing visualization of human anatomy was developed by the University of Newcastle, its results being presented at the same meeting. These results demonstrated that dissection remains a crucial tool in anatomical education, the hypothesis that it might be easily overcome in the future, not to be considered.

Once again, anatomical educators were divided by taking a clear stand in favor of dissection or by opposing and being skeptical to its use in medical education (Chytas et al., 2020; Franchi, 2020; Ooi & Ooi, 2020; Pearson, 2020; Ravi, 2020; Bond & Franchi, 2021; Ross et al., 2021; Saverino, 2021; Tucker & Anderson, 2021). Although cadaver dissection has been further shattered and crawled by the Covid-19 pandemic and innovative teaching strategies have been improved (Saverino, 2021) resulting a promising tool in anatomical education, they cannot replace cadaveric dissection entirely (Ross et al., 2021).

Here the authors, partially and respectfully disagree with Saverino's idea of how medical students should learn anatomy. Anatomical education builds the foundation for a safe, efficient, and effective medical practice and helps students, better than any other electronic or modern tool, to experience and understand the three-dimensionally complex anatomical structures, their variation, and diversity (Brenner et al., 2003; Turney, 2007; Romero-Reveron, 2020; Ross et al., 2021). Cadaveric dissection goes beyond the mere teaching of morphology: smells, touches and incisions cannot be simulated perfectly, making learning anatomy with virtual dissection unrealistic (Brassett et al., 2021; Onigbinde et al., 2021; Patra et al., 2021a).

Promoting empathy, love, and resilience dissection helps students to develop compassion as well as other crucial skills (NTDIS) simply because a patient is a real person. Students recently reported autopsies most beneficial in learning anatomy and dealing with one's own emotions related to death. Moreover, this experience improved their interaction with the relatives of a deceased patient and for people skills (Pakanen et al., 2022). Students need to learn how to match theory, practice, and patient care, the exposure to social media and related web platforms further challenges physician ratings through unfiltered patient feedback. Therefore, the development of human skills, resilience, emotional intelligence, situation awareness, skills in leadership, communication, and human sensitivity on a par with clinical skills and professionalism, is crucial in a future clinician's career (Yule et al., 2006; Evans et al., 2018; Stephens et al., 2019; Evans & Pawlina, 2020). Students must learn to see patients (even if cadavers) as human beings and treat them accordingly. Physician's virtues such as empathy and caretaking cannot be taught by software. Moreover, the deepest essence of medicine lies not only in the treatment

of diseases but also personal engagement between caregiver and patient (Pearson, 2020; Jones, 2021).

## Limitations of the study

Although the vaccination campaign begins to give encouraging results, the Covid-19 pandemic is long far to be fully resolved. Recently, some countries have experienced lockdown once again and have enforced social distancing measures. To the best of authors' knowledge, distance learning is still ongoing in some countries worldwide. For example, in Italy remote teaching has not been completely overcome. Moreover, the current pandemic situation determined a varied landscape and definitive findings of the long-term effect of Covid-19 pandemic are not available so far. Also, the effects that the Covid-19 has had, and is currently having, on the anatomical sciences is a current topic of discussion and the number of published papers is increasing from day to day.

Therefore, this manuscript might be a little precocious, since it is not able to provide conclusive results; nevertheless, it represents the first attempt to systematically review at least the short-term effects that Covid-19 pandemic had on anatomical education worldwide.

Moreover, the authors didn't analyze the non-narrative data statistically since a quantitative analysis was not the aim of this systematic review. Nevertheless, the inclusion of these data might be considered a preliminary and non-quantitative overview of the literature.

## CONCLUSIONS

Looking back over contemporary history, nothing has affected higher education as much as the Covid-19 pandemic since World War II. ["Anatomists should all take pride in how they have coped in the pandemic; ...] Never before has anatomy been so international and so without barriers" (Smith & Pawlina, 2021). "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" (Naidoo et al., 2021a).

The vast majority of the Institutions is moving toward a mixed-approach (activity in presence in the various anatomy facilities/electronic blended lectures and tutorials online) that likely will be the cornerstone of the present (2021) and future anatomy education.

The authors strongly believe that the best anatomy teaching practice requires the careful adaptation of resources, methods as well as the tailored arrangements to the specific skills students and trainees need to acquire. Anatomical educators will not abandon the old pedagogies; they will just integrate them within the new ones.

## ACKNOWLEDGMENTS

The authors wish to thank Prof. Bronwen Hughes for English proof-reading. They also wish to thank Dr. Claudia Maulini for supervising the methodological approach used in the qualitative synthesis.

## CONFLICTS OF INTEREST

None of the authors have a conflict of interest to declare.

## ORCID

Veronica Papa  <https://orcid.org/0000-0002-9995-1097>

Mauro Vaccarezza  <https://orcid.org/0000-0003-3060-318X>

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## AUTHOR BIOGRAPHIES

**Veronica Papa**, B.Sc., Ph.D., is an assistant professor in the Department of Motor Sciences and Wellness, School of Science, Engineering and Health, University of Naples "Parthenope" in Naples, Italy. She is a senior research associate at the Forensic Anthropology, Paleopathology and Bioarchaeology (FAPAB) Research Center. She teaches anatomy to first-year sports science students and clinical anatomy to postgraduate and graduate (Ph.D.) students. Her research interests include anatomical education and cardiovascular disease.

**Elena Varotto**, B.A., M.A., P.G.Dip. (It. M.U.I.), is a researcher in forensic anthropology and bio-archaeology in the College of Humanities, Arts and Social Sciences at Flinders University, Adelaide, South Australia, Australia. She is also deputy director of the Forensic Anthropology, Paleopathology and Bioarchaeology (FAPAB) Research Center. She studies human remains from pre-history up to the present day working with legal courts.

**Massimo Galli**, M.D., is a full professor of infectious disease and Chair of the Department of Biomedical and Clinical Sciences "Luigi Sacco," at the University of Milan, Milan, Italy. His research interests are in HIV and HCV infections, Covid-19 pandemic and the history of human infectious diseases.

**Mauro Vaccarezza**, M.D., Ph.D., F.H.E.A., is a senior lecturer of anatomy and physiology in the Curtin Medical School, Faculty of Health Sciences at Curtin Medical School in Bentley, Perth, Western Australia, Australia and associate investigator at Curtin Health Innovation Research Institute (CHIRI), Faculty of Health Sciences, Bentley, Perth, Western Australia. He teaches human anatomy, physiology and pathophysiology to undergraduate and medical students. His research interests include science of learning and anatomy education, cardiovascular biology and clinical research.

**Francesco M. Galassi**, M.D., is an adjunct professor at the Department of Biomedical and Neuromotor Sciences, University of Bologna, Bologna, Italy. He teaches human and clinical anatomy to undergraduate medical students. He is a paleopathologist and physician and studies the antiquity of disease using a multidisciplinary approach. He is also Director of the Forensic Anthropology, Paleopathology and Bioarchaeology (FAPAB) Research Center at the University of Catania in Sicily, Italy, a center dedicated to the study of human remains.

## SUPPORTING INFORMATION

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**How to cite this article:** Papa V, Varotto E, Galli M, Vaccarezza M, Galassi FM. 2022. One year of anatomy teaching and learning in the outbreak: Has the Covid-19 pandemic marked the end of a century-old practice? A systematic review. *Anat Sci Educ* 15:261–280. <https://doi.org/10.1002/ase.2162>