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Review

Medical and Surgical Education Challenges and Innovations in the COVID-19 Era: A Systematic Review

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Abstract. *The aim of this systematic review was to identify the challenges imposed on medical and surgical education by the COVID-19 pandemic, and the proposed innovations enabling the continuation of medical student and resident training. A systematic review on the MEDLINE and EMBASE databases was performed on April 18th, 2020, and yielded 1288 articles. Sixty-one of the included manuscripts were synthesized in a qualitative description focused on two major axes, "challenges" and "innovative solutions", and two minor axes, "mental health" and "medical students in the frontlines". Shortage of personal protective equipment, suspension of clinical clerkships and observerships and reduction in elective surgical cases unavoidably affect medical and surgical education. Interesting solutions involving the use of virtual learning, videoconferencing, social media and telemedicine could effectively tackle the sudden cease in medical education. Furthermore, trainee's mental health should be safeguarded, and medical students can be involved in the COVID-19 clinical treatment if needed.*

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In December 2019, a case series of a novel type of pneumonia was reported in Wuhan, China. The causing viral agent was identified as a novel betacoronavirus, named SARS-CoV-2, and the respective infection was named as "Coronavirus Disease 2019 (COVID-19)". As of today, COVID-19 has affected world health to an unprecedented degree. More than 2.44 million cases and 165,000 deaths worldwide have been reported as of 20th April 2020 (1).

The pandemic and subsequent mitigation measures have severely impacted all but the most essential activities, effectively shutting down operations in commerce and services. Education has also been disproportionately affected, as the congregation of the youngest members of the community in closed spaces can significantly contribute to the spread of the virus. In total, more that 900 million learners in all levels of education, including higher education, have been affected (2, 3).

Medical education equips clinicians with the knowledge and skills to provide safe healthcare to patients. Those receiving medical education do so, ultimately to provide this service to patients, an essential process to ensure a competent workforce. However, those recipients have responsibilities primarily towards service provision and supporting their health system, particularly in times of crisis. This is exemplified by the shutdown of academic institutions worldwide, reallocation of academic trainees into clinical roles and cessation of mandatory training and teaching. Many trainees have been prevented from rotating into new specialties or training positions and supplementary research and audit work that is not essential has been postponed. The aforementioned measures, whilst drastic for medical education, are seen as necessary to ensure health systems can cope with the burden COVID-19.

The shutdown of academic institutions, alongside the novel challenge imposed on health care systems worldwide (3), have taken an immense toll on the quantity and quality of medical education. Medical students and junior doctors are thus faced with the oxymoron of not receiving adequate education but being required to potentially serve in the frontlines. How can medical students and residents bridge the gaps created in their training, and ensure that they will continue to receive the knowledge and skills required to progress as competent and safe clinicians?

In this systematic review, we attempt to elucidate the existing challenges enforced in medical and surgical education due to the COVID-19 pandemic, as well as the educational methods that can ensure continuity in the education of medical students and junior doctors.

Systematic Review Protocol

A systematic review was conducted based on a predesigned protocol, in order to identify all studies reporting or commenting on the rising challenges in medical and surgical education at the undergraduate and postgraduate level, as well as the adjustments and new tools required to adapt to the new status quo. The review was in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (4).

Search Strategy

We searched all articles listed in the MEDLINE and EMBASE databases, until April 18th, 2020. The search strategy was based on the following algorithm: (coronavirus OR SARS-CoV-2 OR COVID-19) AND (teach* OR education* OR train* OR student* OR resident*). We supplemented our search *via* manually looking into the reference lists of all included articles for additional eligible studies, using the "snowball" method.

Inclusion and Exclusion Criteria

We aimed to include any published article which discussed the impact of Covid-19 pandemic on medical and surgical education. All study designs were included due to the paucity of Class 1 evidence due to the recency of the pandemic and infancy of the literature. Upon first screening of the literature, the scarcity of available sources obliged us to include any study design. Hence, any article that was deemed eligible was considered for full-text screening; this included case reports, case studies, case control studies, cohort studies and randomized control trials. Also, we included letters to the editor, commentaries, editorials, perspectives, "How I do it" reports, as well as any potential reviews or meta-analyses. Selection was limited to articles published in English.

We further specified our Population Intervention Comparison and Outcome (PICO) criteria to define certain inclusion and exclusion criteria. Population included medical students, residents and fellows. All articles limited to school education reports, non-medical students, students of other paramedical specialties, such as veterinary, dental or nursing students, as well as education reports for non-professionals were excluded. The interventions included any innovation in medical and surgical education, amidst the COVID-19 pandemic. Studies about medical or surgical education in other pandemics were excluded, as were innovations during the COVID-19 era not related to medical education. Comparison could not be performed in this research design, and the Outcome was defined as the impact (benefit) of such interventions towards the education of medical students and junior doctors during the COVID-19 pandemic.

Study Selection and Data Extraction

After manually removing duplicates found in the two databases, two authors (AD and MGS) independently scanned the titles and/or abstracts of all articles, applying each time the inclusion and exclusion criteria. Upon completing the title and abstract screening, both authors shared their results. In order to maximize sensitivity, only articles that were excluded by both authors during the title/abstract screening were eventually left out of the full-text screening. Furthermore, articles without abstract were included for full-text screening and assessed at that stage. For full-text screening, both authors performed the screening separately once again, and upon completion, they shared their results. Any conflicts were resolved by discussion with the senior authors (MS/PD). The included articles were then processed for qualitative analysis, and the relevant information concerning the burden of the disease, occurred challenges and suggested innovations during the COVID-19 pandemic were grouped in discrete thematic axes; these thematic axes were expanded in detail in the discussion section.

Quality Assessment of the Studies

We performed structured and critical synthesis of the available data in thematic axes. Given the fact that literature comprised from a huge variation of study designs, quality assessment of those was mainly performed *via* critical appraisal of each article between all authors. For each paper, we concluded to a key message which was then incorporated in the discussion.

Search Results and Thematic Axes

The search algorithm yielded 1080 articles from the MEDLINE database, and 804 from the EMBASE database. After removal of the duplicates, 1288 articles were scanned,

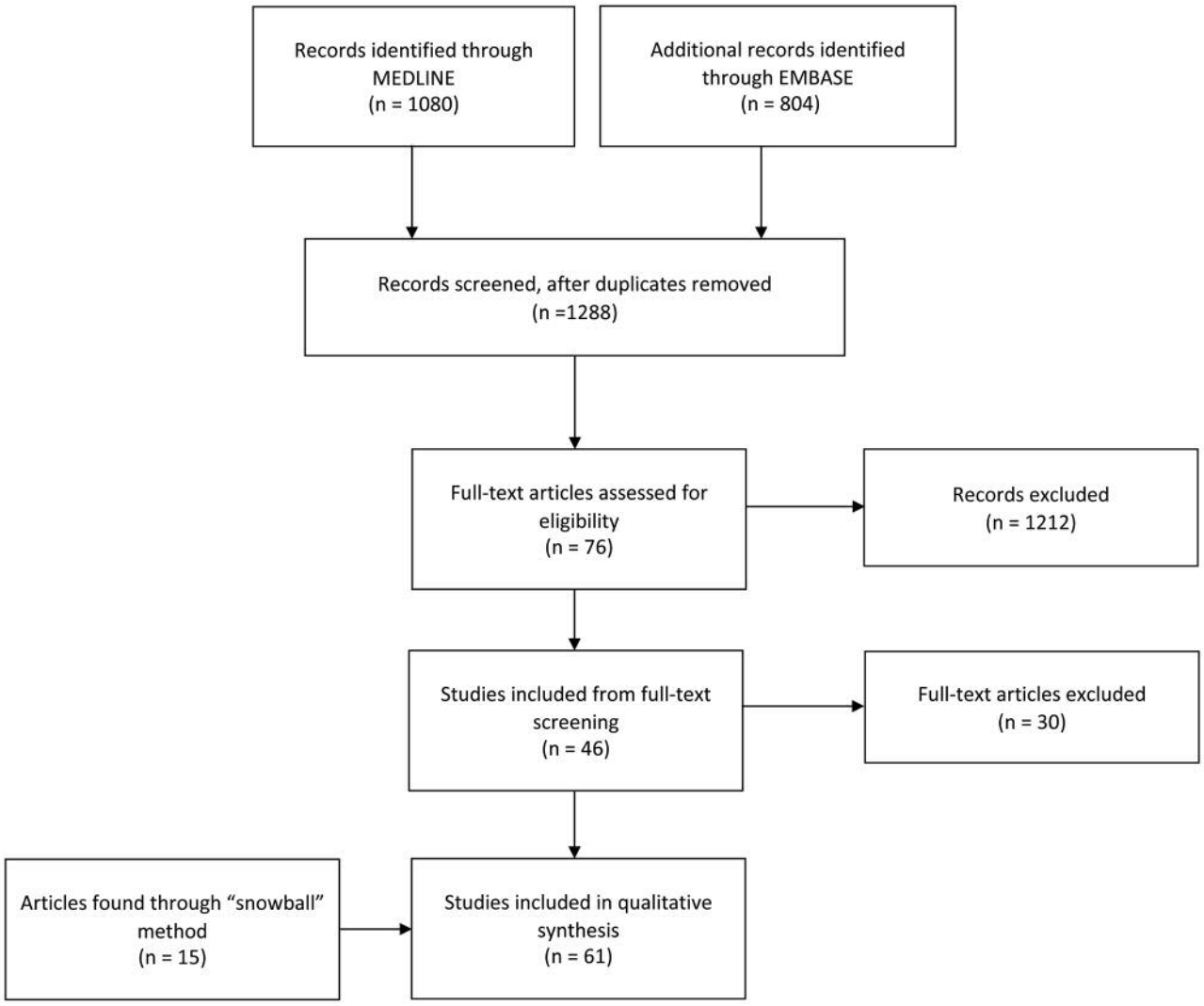

Figure 1. *Flow-diagram of the search strategy.*

based on their title and abstract, and a total of 76 articles were processed for full-text screening. After the full-text screening, a total of 46 articles were included for data extraction. Through the reference lists of the 46 included articles, 15 more articles were finally included in our analysis. Sixty-one papers were analyzed in total. The study selection flow-diagram (Figure 1) depicts in detail our research.

The articles that were included in the analysis were scanned and their key points were summarized in a separate file. Upon completion of the analysis of each article, their findings were assembled in two major axes, "challenges" and "innovative solutions", and two minor axes, "mental health" and "recruitment of medical students to the frontlines".

The "Challenges" axis was divided in two secondary themes, namely the impact on Medical and Surgical Education. Within the "Innovative Solutions" axis, seven secondary themes were identified: Tele-conferences & webinars, Online learning, Social Media, Virtual consults - Tele-medicine, Simulation and virtual reality, Assessment of knowledge and skills and remote learning in anatomy.

Challenges: Impact of the COVID-19 Pandemic on Medical and Surgical Education

Medical education. All aspects of medical education have been severely impacted by the pandemic. The first activities to be suspended under the state of emergency in teaching hospitals were medical students' clinical clerkships, observerships and elective opportunities. As both clinical

training and lectures were deemed unsafe due to social distancing measures, these traditional training methods have been gradually replaced by live or asynchronous online modalities (5). The contagious nature of this disaster has precluded students from being active members of clinical teams, as hospitals attempt to minimize non-essential staffing in clinical environments. The shortage of coronavirus tests and personal protective equipment, as well as the suspension of regular clinical care (*e.g.* outpatient clinics, elective surgeries) has contributed to this difficulty in including medical students. In contrast, other natural disasters (*e.g.* September 11, various fires) have benefited from the students' help and have served as fast-paced clinical learning experiences for them (6). As a result of this disruption, medical students were moved away from bedside training which is a vital component of the undergraduate training. Despite the educational value and diversity of the available online resources, lack of bedside teaching, compromises students' direct involvement with patients, which could have optimised their physical examination skills as well as several non-technical skills (7). Furthermore, in-person clinical assessment is halted (8) preventing medical student engagement with feedback through direct observation of skills or supervised learning events.

The disruption of medical education further extends to residents and fellows. Despite the increased responsibility and workload in certain COVID-19 teams, the holistic, educational aspect of residency and fellowship training is often deprioritized in favor of service provision. Clinical teams tend to be smaller, with a fraction of the residents staying at home in order to ensure availability of backup personnel in the event of virus infection in the clinical team (9). The reluctance of many hospital systems to endanger their trainees further limits their overall experience and education (8, 10, 11). Moreover, the transfer of trainees to pandemic-related services has focused staffing around emergency medicine, intensive care and general medical specialities.

Surgical education. Surgical trainees face even greater challenges during the COVID-19 pandemic (12, 13). In many countries only urgent or emergency surgery is being performed, supported by guidelines from governments, societies and regulators (14-20). Therefore, elective surgeries are being postponed and the number of available learning opportunities is reduced. The elective cases for benign disease that are mostly affected, are the ones that residents usually performed with minimal supervision, in contrast to the more complex urgent or life-threatening operations that are mostly performed by attendings (21). Regulations permitting only essential personnel in the operating room further reduces the available training opportunities (14, 16). Shortage in personal protective equipment (PPE) creates the need for rationing, further limiting the residents' opportunities to attend, observe and assist (9). In addition, attendings tend to take over simpler cases that used to be entrusted to senior residents, in order to reduce the operating time and thus the risk of COVID-19 infection (21).

In the ward setting, daily activities are drastically reduced, and in many cases unsupervised, as attendings may be redeployed to the emergency department (21). The Accreditation Council for Graduate Medical Education (ACGME) and other regulatory bodies require that residents managing patients with suspected or confirmed COVID-19 have adequate supervision by trained faculty. Lack of such supervision can hence postpone operations to sustain a manageable and safe workload (9). Also, ward round teams include only the necessary personnel (9). Case discussions and departmental meetings are cancelled because of social distancing and staff availability concerns (18, 21, 22). Adjacent to this, all conferences, congresses and meetings have been cancelled (17), further reducing the opportunities for continuous education of trainees. Lastly, the de-specialization and redeployment of residents in departments with greater demand in healthcare personnel may address urgent service needs but disrupts residency education plans and may pose future issues with board requirements (12, 17, 23).

Minimizing the Educational Gap: Implementation of New Technologies

Tele-conferences & webinars. Teleconferences had been introduced as useful means of continuous education way before the COVID-19 pandemic. A prominent use of this technology involved reciprocal teaching conferences between world-class, highly specialized academic institutions and smaller hospitals in developing countries (24-26), which have proven mutually beneficial (25) and popular (26, 27). They have been implemented in both surgical (28-30) and medical specialties (31, 32). However, it was not until the COVID-19 pandemic that videoconferencing became the cardinal means of didactics and clinical education (7-9, 17, 33, 34), proving its usefulness (35). Applications such as Google Hangouts (16), Skype (24), Zoom (8, 18), GoToMeeting, WebX (14) or other virtual meeting multimedia (36) allow clinical departments to implement lectures and teaching sessions for medical students or residents (7, 16, 37), morning or evening reports and case discussions (21), journal clubs (17, 38), platforms for updating residents on most recent guideline updates (38) or small group Q&A sessions on everyday practice, PPE use and hospital policies (33).

In light of the sudden need to manage an unknown disease that can result in a domino of complications, webinars can also be applied for interdisciplinary learning. For instance, rheumatologists and immunologists can teach emergency and

intensive care specialists on cytokine storms and hyperinflammation in COVID-19 patients, thus contributing indirectly to evidence-based clinical management (8).

In a larger scale, academic societies can use these difficult circumstances to promote scholarship and academic discourse. A notable example is the "Virtual Visiting Professor" initiative by the Congress of Neurological Surgeons (9).

Online learning. The curricular reforms undertaken by many academic institutions worldwide in the past decade, mainly promoting flipped classrooms and active learning, have facilitated an easy transition of preclinical learning to an entirely online exercise (39). The flipped classroom model and other hybrid modalities can be easily transitioned to an online format, by retaining the online asynchronous instruction, that has already replaced lectures, and converting small-group discussions and exercises to video conferences (7, 16, 40). Indeed, there is prior evidence that such active techniques are preferred by trainees (41).

Clinical education is harder to move online, but steps can be taken to ensure as much clinical exposure as possible. To overcome the lack of hands-on clerkship experience of medical students, Imperial College London has given access to an online video library of patient encounters and encouraged clinicians to deliver online teaching from the hospital where possible (42). Educational conferences can be recorded and uploaded to a cloud or sent to students or residents, allowing them to revise the concepts (14). With regard to surgery, video libraries are particularly beneficial (21, 43). Group viewing has been proposed as a more interactive and motivating exercise (30, 44, 45) and the additional commentary by experts can add educational value (21).

Online atlases such as "The Neurosurgical Atlas", a free online multimedia resource for neurosurgical anatomy and operation images, have been on a significant increase in the number of subscribers during the pandemic, particularly from countries severely impacted by COVID-19 (17, 46).

Another tool promoting self-paced and in-depth learning is podcasts. These prerecorded audio files have been used for a long time in entertainment and news. However, their rediscovery as a vital teaching tool has shown a promising alternative (5, 21, 33).

Online tools should incorporate as much interactive technology as possible, to provide active, engaging learning (5). Online picture diagnosis quizzes in image-centric specialties, such as dermatology or radiology, can prove invaluable for the continuous medical education of trainees.

Social media. Social Media could also serve as an easily accessible and quick resource to encompass medical education (37, 47). Twitter plays a pivotal role in many clinicians' continued education, and journal clubs or "tweetorials" (clinical tutorials in a series of tweets providing links to educational material) can enable residents and medical students to interact with world leaders in their areas of interest (21, 33). This suggestion is not unfounded: the incorporation of Twitter in routine clinical learning has been shown to affect the trainee's clinical practice (48). The use of hashtags (*e.g.* #COVID19training, #MedEd) reinforces the spread of information and sense of community. Facebook has also functioned as an alternative platform for discussion among residents on clinical matters and board exam preparation (14).

Virtual consults, telemedicine. Virtual consults as part of telemedicine are extensively utilized for safe and effective patient care as well as resident education amidst the pandemic. Efficient collaborative tools involving both residents and attendings have been reported in a variety of specialties, such as surgery (14), dermatology (49), allergy (38) and rheumatology (8). In all published paradigms, the resident initially logs into the "virtual room", monitors and interacts with the patient, gathers the medical history and clinical presentation. Briefly logging out, the resident then presents the consult, assessment and plan to the attending. After a discussion, they both re-enter the virtual room and inform the patient and/or primary provider. The presence of the patient during the discussion is also encouraged, as the patients are receptive to this (49). However, the glaring limitation of this method is the inability to perform a physical examination, with clinicians relying solely on remote data (7).

Interestingly, another innovative approach implemented recently in the US teaching hospitals has managed to provide adequate clinical exposure to medical students while relieving some of the clinical workload. Students perform structured video-based encounters with live patients who present to the Emergency Department, aiding in triage (50). Residents can also participate in virtual care from home (37).

Simulation and virtual reality. There is an increased interest for simulation programs at home, which could ensure continuity of technical skills training during the COVID-19 pandemic, particularly in highly technical and demanding surgical specialties. The Hong Kong Eye Hospital set the example, implementing an oculoplastic simulation program using goat eyes with eyelids (36). After broadcasting the procedure, trainees were asked to perform the simulated operation under supervision.

Although most simulation training programs in hospitals have been suspended as non-essential activities (21), they can also be repurposed as rapid and effective training modalities for coronavirus preparedness (51). For instance, demonstration of aerosol contamination through airway management can be performed for trainees in the emergency department and anaesthesiologists treating patients with COVID-19 disease, as the benefits of proper training could outweigh the risk of transmission during this activity and

improve clinical outcomes (52).

Assessment of knowledge and skills. Besides providing knowledge and skills through a variety of recourses, the assessment of these acquired skills constitutes an intrinsic part of education that has to be adapted to the new conditions. This can be achieved through the reinstitution of oral examinations *via* teleconferences, or through simulation programs, video-supervised by clinical educators. Lewis et al. (18) detailed their experience of anastomosis "friendly competition" simulation sessions, with the use of the Chamberlain Group pocket vessel anastomosis simulation kit. The values assessed were the time to completion, quality of the anastomosis and economy in hand motion of the trainee. Assessment can also be performed in virtual visits of trainees with patients, under the supervision of attendings (8), as well as through online tests (34).

Remote learning in anatomy. Anatomy education relies heavily on face-to-face, hands-on teaching and assessment, including cadaveric dissections, protections, models. As a result, the suspension of these activities has caused concern among students (53). However, it has long been recognized as a welcoming platform for new, multimodal teaching methods, including online learning (54). Online innovations such as 3D models can even enhance the learning experience (55). All these ideas and resources have proven useful to the community of anatomy educators, which has turned to a social media discourse in order to exchange ideas, seamlessly transition to effective online teaching and provide support (54). Online teaching needs to remain active, reciprocal and engaging (for instance, avoiding videos of hour-long lectures), and such rapidly devised innovations may even carry forward to the post-COVID-19 era (54).

Trainee's Mental Health

An undisputed part of the education and nurture of medical students and residents is the safeguarding of their mental health. Residents have expressed concerns regarding clinical care, the most crucial ones being the lack of personal protective equipment, inadequate training for combatting this new reality, and the risk of infecting their loved ones at home (34, 56). Their concerns also extend to educational requirements, board certifications or other obligations dictated by their curriculum. Medical Students are also impacted (57), and the uncertainties concerning their education generates stress and anxiety (58), while the social distancing unavoidably results in loneliness (59).

In order to tackle these concerns, free meals to residents are given in some hospitals (33, 34) and virtual Q&A meetings with residents and faculty on gray topics are organized (34). Furthermore, wellness counselors and therapists (34) or other stress management resources (8) are available for residents. Lastly, virtual "social hours" play a pivotal role in managing the overwhelming stress during the COVID-19 pandemic (60).

Medical Students in the Frontline

With the COVID-19 pandemic putting unprecedented pressure upon healthcare organizations, the recruitment of final-year medical students to the frontlines has been an issue of intense debate during the previous months, both in the UK and in the US (61-67). As described above, clinical rotations were suspended in most teaching hospitals worldwide. The opposing view has posited that medical students should not be left out of the healthcare workforce. Instead, they could be of aid in the outpatient setting, non-COVID-19 inpatient wards or remote COVID-19 patient care from home (68). The benefits could be higher than the risks, and this would instil professionalism, altruism and solidarity. Alternative ways to help, such as staffing call or helping with groceries, or volunteering in organizations, have also been implemented (39, 69).

Final-year medical students constitute a critical, clinically competent part of the healthcare workforce (70). Some universities have offered early graduation options to senior medical students who have completed their degree requirements (66). Other forms of compensation, including a salary, loan repayment, tuition rebate incentives by the federal government or credit towards residency completion have been proposed (70).

Strengths and Limitations

The strength of our study is that, to our knowledge, this is the first systematic review on medical and surgical education during the COVID-19 pandemic, focusing and summarising the challenges as well as innovations in order to bridge this education gap. The main limitation of our study is the scarcity of the available literature, which dictated us to broaden the criteria of our review in order to include all types of manuscripts and thus lowered the quality of our review. However, the justification of this review is that the rapid spread of the COVID-19 disease and the subsequent disruption of medical education created the need to promptly evaluate and discuss the available methods that have been applied worldwide in order to bridge this educational gap.

Commentary

This review can be used only as a guide for innovative solutions that have been proposed and implemented in many academic medical centers worldwide. Our aim was to illuminate the current situation and discuss any available information on how to best tackle this new status quo and create a contingency plan for continued education. Amid this extraordinary emergency, challenges can be transformed into opportunities, and pave the way for education to progress and grow, mainly thanks to the availability of technological advancements which can be incorporated in everyday medical education. It is a great challenge nonetheless, both

for trainers and trainees, but, as Koumpouras et al. stated, "[trainees'] education must continue, and [trainers] must stand shoulder to shoulder with them and deliver"(8).

Conclusion

Medical and surgical education have been severely affected by the COVID-19 pandemic, but this emergency has fortuitously provided an impetus for pedagogical novelties. This could create a legacy for medical education in the future, once this healthcare emergency is under control. This systematic review summarized the available literature on the issue, which mostly consists of anecdotal communications without empirical evidence, due to the short time window and unexpectedness of the COVID-19 pandemic. There is a great need for qualitative and quantitative studies on the proposed methodologies. The long-term impact of the pandemic on the educational gaps of medical students and residents remain unknown, and a retrospective study will be required in the future to address this issue.

Conflicts of Interest

MGS has received research support from Mallinckrodt Pharmaceuticals, unrelated to the present review.

Authors' Contributions

MS and PD conceived the study and supervised the project. AD designed the search strategy. AD, MGS and JGH analyzed and interpreted the data. AD, MGS and JGH drafted the manuscript. JGH, PD, DJ and MS revised it critically for important intellectual content. All Authors approved the final version.

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