

An analysis of medical education suggestions and interventions during the COVID-19 pandemic: A literature review

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Abstract

Purpose: Medical education systems were heavily impacted by the public health measures implemented due to COVID-19. This literature review serves to summarize and discuss the strengths and limitations of novel medical education interventions or proposed suggestions during the COVID-19 pandemic in order to assist medical institutions with the evaluation of various interventions prior to their implementation.

Method: The research team conducted a scoping review following the Arksey and O'Malley framework. MEDLINE and EMBASE were searched for publications from January 1st, 2019 to August 10th, 2020 that proposed novel medical education interventions or suggestions during the COVID-19 pandemic. The search included MeSH searches, titles, abstracts, and keywords of studies. Our inclusion criteria was comprised of articles that used qualitative designs; included medical students as the primary study cohort; involved suggestions for new medical education strategies to accommodate for the COVID-19 changes; involved studies that assessed the challenges and strengths of new COVID-19 medical school interventions; were primary studies, reviews, published letters to an editor, or opinion pieces.

Results: The final number of articles included in this review was 54. Each article had one or more interventions proposed. 10 articles reported integrating medical students in the workforce. 7 articles discussed efforts to manage medical students' stress. 5 articles described changes to the residency program application process. 10 articles discussed changes to examinations. 12 articles discussed changes to clinical rotations and electives. 11 articles discussed implementing online clinical experience. 36 articles implemented or suggested online learning strategies.

Conclusions: The literature review suggests that quantitative studies to assess the efficacy of each intervention is still required given the differences in suggestions offered by different institutions across the world.

Introduction

The onset of novel coronavirus disease (COVID-19) pandemic posed a major challenge to the healthcare systems around the world.¹ To combat the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), contact tracing, quarantine, and social distancing measures were implemented due to the lack of widely available and effective pharmaceutical interventions.²⁻⁴ To maintain social distancing, several countries around the world announced the closure of places with large public gatherings, including museums, gyms, venues, businesses, schools, and universities.³⁻⁴

The nationwide closures of educational institutions in 150 countries around the world as of March 25th, 2020 impacted over 80% of the world's student population.⁵

Education systems were heavily impacted by these public health measures. Students had to continue the curriculum online from home following the closure.⁵⁻⁸ Campus resources were no longer available and on-campus learning activities such as lectures, volunteering, and research experiences were halted.^{5,6,9} Faculty members and educators faced challenges in quickly updating the curriculum in order to adapt to these new measures.⁶ Faculty had to make difficult decisions related to shortening or removing parts of the curriculum, implementing a fair evaluation policy, and transferring in-person lecture material to online platforms in a short amount of time.^{6,7} In

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addition, faculty also had to assist students to navigate through the uncertainty surrounding examinations and credit evaluations as well as the potential impact on future applications.⁵

Medical students in particular were faced with limited clinical exposure and faculties had to balance between the safety of the students while ensuring that relevant hospital clinical exposure was obtained.⁷ A significant challenge faced by medical school faculty was being able to provide authentic clinical experience and patient interaction, which are key components of medical education.^{7,10} With any curricular changes, the faculty had to incorporate adequate clinical and academic competencies to ensure that medical students are trained with the necessary knowledge and skills that would help them become qualified physicians.⁷

Medical education has been trying to implement new technological innovations for many years.^{11,12} The changes recommended focused on reducing in-person lectures, using technology to supplement or enhance anatomy and laboratories, implementing active, team-facilitated, and self-directed learning, and promoting interprofessional education.^{11,12}

Amid this pandemic, innovative changes in medical education must be evaluated and reflected upon to ensure that practical interventions and solutions are implemented to the curriculum in a timely manner.¹² Some studies have begun assessing the efficacy of novel interventions however, a collaborative effort across schools and facilities is required to determine whether the novel interventions will help students receive quality education during these difficult times.¹³⁻¹⁶

This review serves to summarize and critically analyze novel medical education interventions or proposed suggestions during the COVID-19 pandemic. It also aims to address knowledge gaps of effective interventions in medical education during the COVID-19 pandemic by discussing the strengths and limitations of interventions involved. This review will assist medical education departments across the world to take an approach to evaluate the types of interventions and their effectiveness before successful implementation.

Methods

Relevant research studies

The research question for this study was agreed upon by the research team. The articles were obtained from the electronic databases MEDLINE and EMBASE. The search included MeSH searches, title, abstract, and keywords of studies. We selected our articles using the following search terms identified by the research team: medical student [Mesh and Keyword], medical education [Mesh and Keyword], AND COVID-19 [Mesh and Keyword], pandemic [Mesh and Keyword], Corona virus [MESH], health facility closure, undergraduate medical student, quarantine [Mesh and Keyword], social isolation [Mesh and Keyword], AND research [Mesh and Keyword], research report [Mesh and Keyword], medical research, qualitative research, biomedical research, peer-review research [Mesh and Keyword]. The articles selected were published from January 1st, 2019 to August 10th, 2020, with the aim of including only relevant articles during the time of the COVID-19 pandemic.

Selection of studies

Our inclusion criteria was comprised of articles that: 1) used qualitative method designs; 2) included medical students as the primary study cohort; 3) involved suggestions for new medical education strategies to accommodate for the COVID-19 changes; 4) involved studies that assessed the challenges and strengths of new COVID-19 medical school interventions; 5) were primary studies, reviews, published letters to an editor, or opinion pieces.

Studies were excluded if they: 1) were not written in English; 2) discussed only changes at the postgraduate level (residency and fellowship) rather than medical school level; 3) were older than 1.5 years; 4) discussed changes in medical curriculum in terms external to the COVID-19 pandemic.

Prior to initiating the screening process, a calibration exercise was conducted by the research team (AAR, NA, GE) to assess

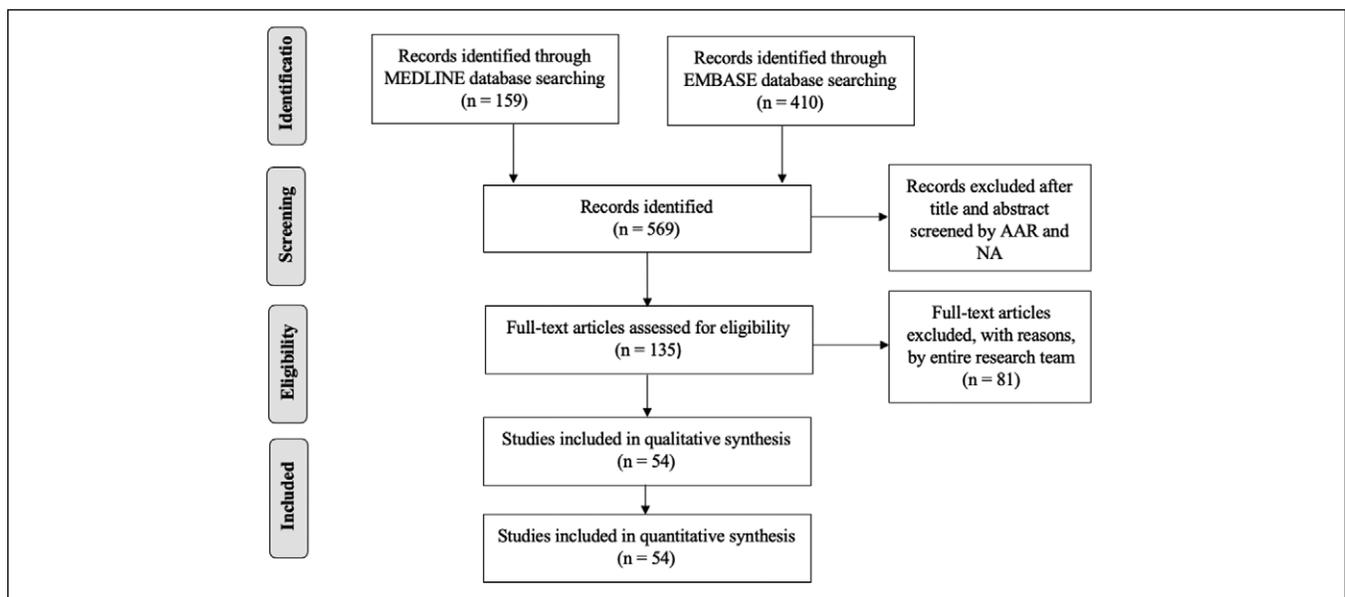


Figure 1. PRISMA flow diagram of selected studies

reliability in correctly selecting articles for inclusion. We utilized the methodologically rigorous scoping review approach proposed by Arksey and O'Malley and advanced by Levac, Colquhoun, and O'Brien.^{17,18} We chose to utilize this specific method as it fit the criteria we believed best encompassed studies within our field of interest. This approach involves five stages: (1) identifying the research questions, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing, and reporting results. We screened a random sample of 10% of the included citations by the three reviewers, independently.

Results

Following the random selection, we had collected a large preliminary list of potential articles comprised of 569 (MEDLINE: 159 and EMBASE: 410) studies that fit within our predetermined search criteria. Following a title and abstract screen, conducted by AAR and NA, the number of articles were reduced to 135 (MEDLINE: 49 and EMBASE: 86). The manuscripts were then read in full by the

researchers to determine relevance to our research question and to assess whether it fit within our inclusion criteria. The final number of articles included in our review was 54 (Figure 1). AAR provided a global oversight of the reviewing process and coordinated with the rest of the researchers. Discrepancies were resolved by consensus or by acquiring the opinion of a third researcher. AAR, NA, GE, and KH were involved in selection of relevant articles based on our inclusion criteria. Articles that discussed any novel interventions, changes, or recommendations were included in the study. Articles that only discussed difficulties faced by medical students, for example, without discussing interventions to alleviate such stressors were not included. In addition, any interventions that were implemented for reasons outside of COVID-19 were also not included. All articles were assessed at least twice by two reviewers and only studies that were agreed upon by at least two members of the team were included in this review. Discrepancies were resolved by consensus or by acquiring the opinion of a third researcher. Results of our review are depicted in Table 1.

Table 1. Summary of COVID-19 medical school intervention suggestions from 54 articles (2019-2020)

Category	Subcategory	Number of Articles	Suggested Intervention(s)	Advantages	Limitations
Medical Students in the Workforce	Expedited entry of medical students into the workforce	5	Fast-tracking medical students into the health-care system without writing the postgraduate examination (9 month shortening) ¹⁹ Offering accelerated licensing processes for students matching into high impact areas ²⁰ Involve final year medical students on the frontlines ²¹ Allow final year medical students in the UK to apply for early provisional registration in hospitals where the healthcare burden is heavy ²² Final year medical students can volunteer in clinical environments to alleviate burden on healthcare system during the pandemic ²¹	Rapid increase in hospital doctors to support high impact areas ¹⁹ Alleviates health care burden ^{20,21} Ease sense of helplessness in students ²¹ Valuable exposure to a unique event ²¹ Students fulfill the altruistic aspect of medicine ²¹ More teaching opportunities for medical students; more experience for final year medical students with both normal and pandemic-specific duties ²²	Short to absent transition process places new doctors at a higher risk of work-related stress ¹⁹ Risk of infection rises ²¹ Lack of training ²¹ Additional work hours may interfere with academic medical education ²¹
	COVID-19 Medical Student Response	5	Student co-directed COVID-19 response team ²³ Medical students were encouraged to volunteer/work within local hospitals ²⁴ Deploying student volunteers in hospitals with the purpose of supporting educational needs ²⁵ Medical students were incorporated into inter-professional teams to compose a weekly report that directly answered COVID-19 questions requested by doctors ²⁶ If the pandemic worsens and there is a demand for personnel, medical students could be trained to provide support on the frontlines ²⁷ Medical students may help spread reliable data on COVID-19 via social media and aid in risk communication and community engagement (RCCE) ²⁷ Medical students can inform patients who might have the seasonal flu (similar symptoms to mild cases of COVID-19) about symptoms, prognosis, and danger signs after which they should seek medical attention immediately ²⁷ Medical students can aid in tracing undiagnosed cases of COVID-19 and offer instruction to individuals on the phone by helping at call-centers ²⁷	Students involved in a task force can obtain an elective credit ²³ Both the healthcare system and community benefited from the response team (e.g. 100+ students in the task force called and instructed over 900 COVID-19 patients about infection control measures) ²³ Volunteers learn about teamwork in health care settings as they shadow doctors. ²⁵ Students were able to practice various didactical, research, and communication skills ²⁶ It would be more productive, time-efficient, and would require fewer efforts to train medical students who have pre-existing education of diseases, epidemiology, and infection control to support the frontlines compared to other cohorts of people ²⁷	Volunteers must be properly guided into working within their capabilities ^{24,25} Medical students lack training ²⁷ Safety of students is compromised ²⁷ Prepare guidelines and standard operating procedures (SOP) in advance specifically for medical students ²⁷ Risk of infection rises ²⁷

Table 1. Summary of COVID-19 medical school intervention suggestions from 54 articles (2019-2020) *continued*

Category	Subcategory	Number of Articles	Suggested Intervention(s)	Advantages	Limitations
Stress Management for Medical Students	General Stress Management	5	<p>Student distress management²⁸</p> <p>Individualized learning plans for each student²⁹</p> <p>Stress management sessions³⁰</p> <p>Psychological support to students³¹</p> <p>Virtual medical student wellbeing support guided by learning advisors⁷¹</p>	Help students reach educational checkpoints ²⁹	<p>Dramatic changes in a short period of time may increase stress in the student population²⁸</p> <p>Teacher-student relationship jeopardized²⁹</p>
	Personal portfolio program	1	Implemented a personal portfolio program for students ³²	Promotes adult learning and setting personal goals ³²	
	Reduction in the volume of new information	1	Reduce the volume of new information to avoid increasing the risk of student distress during the pandemic ³³		
Residency	Residency Application Process	1	Implement institutional virtual events to replace visiting sub-internships ³⁴	<p>May compensate for limited access to residents for professional development³⁴</p> <p>Aids students without home programs who cannot successfully complete away rotations³⁴</p>	<p>Medical students miss out on the opportunity to interact with faculty and residents from beyond the limits of their location³⁴</p> <p>Students will lack the experience gained from participating in away rotations where the training system may vary³⁴</p> <p>It can be more challenging to build close relationships with faculty, residents, and other students during virtual events which normally provides individualized mentorships³⁴</p>
		2	Possibly changing the requirements of graduation and residency applications ^{20,24}		
		1	Limits on the number of applications per applicant ³⁵	Alleviates costs for students by limiting excess applications ³⁵	Disproportionately impacts applicants who may already have lower chances of matching such as international medical graduates, osteopathic medical students, and students with lower standardized testing scores ³⁵
		1	Delaying residency program's access to applicant profiles ³⁵	Allows students to complete more clerkships to gain more clinical experience and confirm their specialty choice ³⁵	May result in residency programs assessing applicant profiles on an accelerated schedule which would prevent them from completing a comprehensive review ³⁵
		1	No evaluations ³⁶		
Examinations	Cancel	1	No evaluations ³⁶		
	Shift to an Open Book Format	6	Online Open Book Examinations (OBEs) ^{24,36-40}	<p>Development of alternative assessment methods³⁶</p> <p>Increase in student satisfaction³⁶</p> <p>Reduction in student anxiety³⁷</p> <p>Primarily constructed to understand information and assess knowledge, rather than searching up answers³⁷</p>	<p>Issues with assessments³⁶</p> <p>Experiencing online open-book exams for the first time may cause anxiety for students³⁹</p> <p>Distractions from surroundings³⁹</p> <p>Students will focus more on studying broad topics since they can use the internet to search for small but key details. This may impact students' core knowledge moving forward³⁹</p> <p>Academic misconduct becomes easier to accomplish³⁹</p>
		6	<p>Online digital spotter examinations or Online Multiple-Choice Questions (MCQ), Extended Matching Questions (EMQ), Short Answer Questions (SAQ), Single Best Answer (SBA) exam^{25,35,41,42}</p> <p>Electronic Objective Structured Practical Exam (OSPE) to replace traditional OSCE⁴³</p>	Development of alternative assessment methods for the future ³⁶	<p>Reliability of network connection^{25,43}</p> <p>Academic misconduct⁴³</p>

Table 1. Summary of COVID-19 medical school intervention suggestions from 54 articles (2019-2020) *continued*

Category	Subcategory	Number of Articles	Suggested Intervention(s)	Advantages	Limitations
Clinical Rotations and Elective Changes	Cancel	5	Cancellation of electives ^{31, 63, 64}		Lack of clinical experience. Limited material compared to the wealth of knowledge gained in rotations ⁴⁷
			Cancellation of clinical rotations ^{42, 65}		Student will suffer financial losses ⁶³
	Maintain	4	Carefully allocating students into low-risk clinical settings ²⁰	Invaluable experience of real-life learning is maintained ⁶⁶	Risk of infection rises ^{20, 67, 68}
			Continue in person clinical rotation ⁶⁶	Students will be provided training on proper handwashing, N95/P2 mask fitting, and aseptic technique with PPE, and will receive formal certification on completion ⁶⁶	Students with risk factors cannot participate ⁶⁷
			Clinical year students may assist in hospitals if they are guaranteed protection, access to PPE, and medical attention if needed ⁶⁷	Opportunity to observe and support healthcare workers on the frontlines ⁶⁷	
Delay	2	Study to assess perception about wanting to return to clinical setting or not resulted in two-thirds of students favouring to return ⁶⁸	Demonstrates students' motivation to be held at the high moral standards of medical professionals and to participate on a medical team ⁶⁸		
		Postponing clinical rotations ²⁹		Disruption of rotations may impact career choice ^{29, 64}	
Shortened Duration	2	Postponing away rotations until it is safe for all applicants and programs ⁶⁴			
		Limits on visiting rotations and shortening their duration ³⁵	Allows for a fairer distribution of what will be a limited opportunity and eases some financial burdens as students will choose one specialty over another ³⁵	Students' opportunities for clinical experience will be reduced which could possibly affect their specialty choice and competitiveness to match ³⁵	
Mixed	1	Shortened hospital-based clinical experiences ⁶⁴	By shortening the duration of visiting rotations, students still get the experience to gauge the environment and see whether they fit with the program, while giving others the chance to experience this specialty ³⁵		
		A 4 week in-person surgery rotation followed by a 2-week virtual clerkship ⁴¹			
Online Clinical Experience	Synchronous Patient Encounters	9	Telehealth experiences ²⁰	Though clinical experience may be compromised, medical students will remain safe ²⁰	This change is unsustainable if rotations are cancelled for a prolonged duration ⁴⁷
			Clinician-supervised phone calls, video calls, communication over medical record application ²⁸	Telehealth practice will likely remain after the pandemic and could possibly become the favored approach for physician-patient interactions ²⁸	Surgery skills can only be perfected in the operating theatre ⁶⁰
			Supervised telehealth visits ²⁹		Experience gained on-the-field cannot be wholly replaced with online courses ⁶⁰
			Third year medical students can complete fourth year elective requirements online until third year clinical rotations can resume ⁴⁷	Ambitious students can innovate new systems for telehealth communications with patients and other healthcare professionals ²⁸	Non-verbal communication skills that are required for real patient encounters were considered difficult to teach online ⁶⁹
			Video guided examination of possibly infected patients ⁵⁰	Allowed students to learn knowledge necessary for graduation ²⁹	
			Telemedicine ⁵⁰	Attempts to make use of time and not jeopardize the quality and quantity of medical education ⁴⁷	
			Appointed a learner to each attending to join the telemedicine visits ⁵⁵	Online education benefited first and second year medical students ⁵⁰	
			Use of tele-technology and augmented reality in which students can experience live proctoring by surgeons and interact remotely ⁶⁰	Online courses for clinical students should permit an almost normal interaction with patients using remote consultation technologies ⁵⁰	
			Interactive patient encounter ⁶⁹	Trainees were able to interact with medical genetics providers and gain insight into their field allowing them to learn about genetics, metabolism, and the complexities of telemedicine ⁶⁵	
			Telemedicine student visits with patients supervised by clinicians ⁷⁰	Can be used to supplement student placements once lockdown restrictions ease ⁶⁰	
			Survey reveals that students considered simulated patient encounters to be more engaging than other online teaching methods ⁶⁹		
			Screen sharing feature can enable students to review radiographs and pathology slides remotely ⁷⁰		

Table 1. Summary of COVID-19 medical school intervention suggestions from 54 articles (2019-2020) *continued*

Category	Subcategory	Number of Articles	Suggested Intervention(s)	Advantages	Limitations
Online Teaching Education	Online Learning	31	<p>Implement online lectures^{20,25,28-33,36,38,40-42,44-57,71}</p> <p>Asynchronous discussion forums, A general meeting for social interactions between teachers and students³²</p> <p>Supplement lecture component with additional resources. Confirm understanding and promote problem solving by using questions and images, communication by students through text-based chat or audio responses, small group discussions during lecture breaks, activities for students to do before the lecture to identify areas of weaknesses, and providing resources to review previous topics learned³³</p> <p>Self-directed learning through the inverted classroom model (ICM) which involves an individual, self-directed learning phase followed by a classroom-instruction phase⁵⁸</p> <p>Incorporation of non-lecture components to online education e.g. case⁵⁹/team⁵⁹-based learning (CBL/TBL), Computer-assisted learning, High-fidelity patient simulation (HFPS), Serious games⁶¹</p> <p>Using online polls, individual-based competitions, and group-based competitions⁷²</p>	<p>Companies associated with educational technology have opportunities to cultivate new e-content²⁸</p> <p>Preclinical students are mostly Gen Z students (1997 or later) who prefer technological integration in their learning and to solve problems using digital methods²⁸</p> <p>Students benefited and satisfied with course content^{31,51,56,57,61}</p> <p>General meeting for social interaction attempts to protect the teacher-student relationship³²</p> <p>Synchronous learning provides opportunities for questions and answers, polls, surveys, quizzes, breakout groups, and discussion forums to enhance students' engagement^{32,33,44,52,55,59}</p> <p>Improvement of technological skills³⁶</p> <p>Collaboration: mobilizes individuals from across the country and around the world to create an online platform that distributes clinical content^{36,38,47,53,57}</p> <p>Minimization of student anxiety³⁸</p> <p>Virtual attendance has been higher than face-to-face attendance⁴⁰</p> <p>Lectures focused on topics with less clinical relevance for students to alleviate demands on clinicians' time⁴⁴</p> <p>Flexibility and freedom to control pace of learning^{42,51,56,61}</p> <p>Increase students' autonomy and allow for the completion of their degrees⁴⁸</p> <p>More cost effective,^{48,61}</p> <p>Students' access to patients and equipment is not required in most nuclear medicine teaching⁴⁹</p> <p>Opportunities for deeper learning through multiple learning mediums^{56,61}</p> <p>Increased medical students' interest, engagement, and participation; promoted retrieval practice; poll system was easy to use⁷²</p>	<p>Technological barriers such as audio bleeding and issues with internet reliability (especially in rural areas)^{25,32,33,46,48,52,53,56-58,61}</p> <p>Students may be at a greater risk of experiencing stress due to the drastic changes to learning over a short period of time²⁸</p> <p>Teacher-student relationship jeopardized^{29,36,56,57}</p> <p>Difficult to focus with distractions from surroundings especially for students lacking self-discipline^{32,33,51}</p> <p>The educator's ability to track student engagement is impaired during lectures due to online platform^{33,52,57}</p> <p>Learner is in a passive position of receiving knowledge if lecture is a one-hour monologue with no student interaction^{33,57}</p> <p>Cultural preferences for face-to-face teaching^{2,48}</p> <p>International students in other time zones and students assisting on the frontlines (e.g. phlebotomists) may find it difficult to participate in synchronous learning⁴⁴</p> <p>Students may participate in other online activities while holding a proxy attendance⁴⁶</p> <p>Lack of proper training for faculty members with no e-learning experience or lack of digital literacy in students^{46,48,52,61}</p> <p>Poor infrastructure with underdeveloped IT departments would cause difficulties and disproportionately affects developing countries^{46,60}</p> <p>Face-to-face is essential for professionalism and clinical skills⁴⁸</p> <p>Chance of learning outcomes not fully met^{48,49}</p> <p>Lack of student engagement. More interaction suggested through polls or quizzes to confirm understanding of material^{56,57}</p> <p>Individual-based quiz competition may have caused students to focus more on achieving a higher score rather than concentrating on the content itself⁷²</p>
	Online Anatomical Education	3	<p>Teaching anatomy using videos, online resources, social media, 3-D printing, augmented Reality, and virtual reality^{36,42,62}</p>	<p>Development of new online resources³⁶</p> <p>Integration of blended learning styles in future curriculum development³⁶</p>	<p>Reduced student engagement³⁶</p> <p>Online anatomy programs are often costly⁴²</p> <p>Dissection is considered the "gold standard" for learning anatomy^{42,62}</p> <p>Potential loss of incorporating ethics education with learning anatomy⁶²</p>

Discussion

Although an extensive amount of information has been gathered since the onset of the COVID-19 pandemic, there still exists a great deal of uncertainties and gaps in our knowledge. In an attempt to fill these gaps, this article reviews the literature pertaining to the interventions that were suggested by various medical schools in response to the COVID-19 pandemic. The purpose of this literature review was to address the strengths and limitations of these suggested interventions and discuss potential solutions.

Through our review of the literature and exploring the strengths and limitations of implementing expedited entry of medical students into the workforce in response to COVID-19, we found diverse opinions regarding its implications on students' wellbeing, experience, and sense of involvement. Early entry of medical students into the healthcare system (e.g. without completion of the postgraduate examination) supported the high demand of physicians during the early stages of the pandemic and offered these students the unique opportunity to gain valuable exposure to pandemic-related tasks.^{19,21} However, this rapid transition may have placed additional stress on fast-tracked medical students, compromised students' health due to the high risk of infection, and made it difficult to ensure they are adequately trained.^{19,21,27} Another intervention suggested by some medical schools was to place medical students into groups (e.g. inter-professional groups and a student co-directed COVID-19 Response Team) to provide an avenue for these students to deliver reliable information about COVID-19.^{23,26} Additionally, medical students can be guided by standard operating procedures and trained to provide support on the frontlines (e.g. helping at call centers or informing mild COVID-19 patients of symptoms and danger signs).²⁷ Gradually introducing students to low-risk hospital wards may mitigate the elevated risk of infection while still providing students with the opportunity to experience real-life learning.^{20,66} Offering expedited entry of medical students into the workforce as an optional part of the curriculum would give students the choice of participating, as some students may be unable to participate (e.g. those who are immunocompromised or those residing with individuals who are at high risk).

Due to the COVID-19 outbreak, drastic changes were made in a very short period of time. These changes may have increased the stress experienced by medical students in addition to the stress typically experienced during medical school.²⁸ Some of the interventions medical schools implemented include stress management sessions for students, tailored learning plans to assist medical students with reaching educational checkpoints, and personal portfolio programs to promote setting personal goals.^{28-30,32} Participation in other stress-reducing activities (e.g. physical exercise, meditation, and social interactions) may also help medical students cope with the stress associated with quickly evolving circumstances.

Implementing changes to residency applications was an intervention set in place by several medical schools during the COVID-19 pandemic. These changes include restricting the number of applications per applicant, delaying residency programs' access to applicant profiles, and hosting institutional virtual events to replace visiting sub-internships.^{34,35} Although restricting the number of applications per applicant lightened the associated costs and inefficiencies, it raised a concern for applicants who already had lower chances of matching at specific programs (e.g. osteopathic medical students, international medical graduates, and students

with lower standardized test scores).³⁵ Delaying residency programs' access to applicant profiles would give students additional time to gain more clinical exposure, ultimately helping them decide their specialties of interest.³⁵ While residency programs may be encouraged to complete a holistic review of medical students' application profiles, time restrictions might not allow for this.³⁵ Lastly, institutional virtual sub-internships served as a platform to help medical students without home programs to access residents for professional development; however, virtual events may not be able to wholly replace the interactions with faculty and residents and the exposure to different institutional environments that are usually provided by away rotations.³⁴

During the pandemic, making changes to assessment methods was a common intervention medical schools put into place in order to ensure optimal success and wellbeing of students. Some medical schools have opted to cancel examinations altogether, while others turned to online open book exams and various formats of online assessments (e.g. multiple-choice questions, extended matching questions, single answer questions, and single best answer questions).^{24,25,35-42} Online open-book examinations (OBEs) were designed to integrate information and test students' knowledge, rather than having the answers readily available on the internet.³⁷ From a student perspective, OBEs increased satisfaction with the testing modality and reduced anxiety.^{36,37} From the medical school perspective, the speedy transition to OBEs called for an extensive amount of time and technical infrastructure.^{36,54} Although this was possible in some medical schools, medical schools in developing countries (e.g. Cameroon and Iran⁷³) with less equipped IT staff and management found difficulties and lagged behind a rapidly changing learning environment.^{46,60} Taken together, the transition to online assessment appears to have successfully met students' expectations and needs in terms of providing a platform in which students can write examinations in a low-stress environment. However, hefty technology and staff are required to buttress such a rapid transition to online assessments in medical school. The attempt to meet the demands of online learning (e.g. internet connection and access to electronic devices) would not only introduce financial burdens, but also require a considerable length of time for medical schools to implement.

Another suggested medical school intervention in response to COVID-19 was to modify traditional clinical rotations. These changes include shortening, cancelling, maintaining, or delaying in-person rotations, or mixing in-person rotations with virtual clerkships. Cancelling clinical rotations took away students' opportunity to obtain recommendation letters and strengthen their residency applications.⁶³⁻⁶⁵ On the other hand, maintaining or postponing in-person clinical rotations through progressively reintegrating students into low-risk clinical settings (given they are guaranteed access to personal protective equipment) allows students to gain the invaluable experience of real-life learning.^{20,66} However, the risk of infection is elevated and therefore students with pre-existing risk factors are unable to participate.^{20,67,68} These differing opportunities among students may introduce inequity, as students without predisposing factors have the choice to participate in clinical rotations while students who are at risk cannot participate. Mixing in-person rotations and virtual clerkships through shortening the duration of clinical rotations in conjunction with virtual learning allows students to still gain the experience of in-person rotations

while protecting the safety of themselves and others.⁴¹ Given the advantages and disadvantages of cancelling, maintaining, or delaying in-person rotations, it seems as though a blend of both in-person and virtual rotations is the safest way to allow medical students to receive hands-on clinical exposure while protecting their health.

An intervention suggested by some medical schools was to implement online clinical experience. Online clinical experience included either asynchronous or synchronous patient encounters. Synchronous refers to events occurring simultaneously; in the context of medical education, synchronous learning tends to be interactive and occurs in real time. Asynchronous refers to events occurring at different times and refers to a method of delivering education that does not occur in real time. Asynchronous patient encounters involved online clinical simulations and screen-based assessments that replaced real patient exams to ensure the safety of those involved.^{24,29} Additionally, video footage of physical signs as well as dysmorphism cases over picture-based Zoom lectures were shown to and interpreted by medical students.^{24,55} On the other hand, synchronous, virtual patient encounters allowed medical students, under the supervision of clinicians, to be involved in telemedicine.^{20,28,29,50,55,60,70} A number of strengths are associated with incorporating medical students in supervised telehealth visits. Telehealth courses are gradually being integrated in medical education and in some circumstances may be the favored route for physician-patient interactions.^{28,70} Therefore, it can be an advantage for medical students to gain experience (e.g. take patient histories, virtually conduct physical exams, discuss potential diagnoses, and plan investigations and treatment) with an emerging method of patient interactions. Although students considered simulated patient encounters to be more engaging than other methods of online teaching, some essential skills (e.g. non-verbal communication and surgical skills) were challenging to develop online.^{60,69,70} The Royal College of Physicians and Surgeons of Canada has created the CanMEDS framework which includes seven core abilities that are considered essential for physicians to have in order to deliver good patient care. These competencies include leader, communicator, collaborator, scholar, professional, health advocate, and medical expert.⁷⁴ While virtual patient encounters provide medical students with valuable experience in telehealth, prolonged online clinical experience will likely interfere with medical students' abilities to develop some of the CanMEDS competencies such as communication. Several barriers such as the extensive demand on time and internet speed associated with relocating clinical care online together with the anxiety related to adapting to a new system can impede the potential effectiveness of involving medical students in supervised telehealth visits.^{58,70} With some technological improvements, online clinical experience may be the best option to minimize potential vectors in healthcare settings.⁵⁴ As the pandemic eases in the future, it may be worthwhile to incorporate a condensed yet descriptive in-person "catch up" course for any aspects of medical education that are extremely difficult to replace with online learning (e.g. anatomy, surgical skills, and patient interactions).

Transferring in-class teaching to online education was among the most common interventions medical schools resorted to during the onset of the pandemic. Online teaching supplemented the in-person lecture component with many virtual resources including general meetings for social interactions between teachers and students, small group discussions to measure level of comprehension, as well as

case-based learning and team-based learning.^{32,22,55,59} Resources were provided to students in order to help them review previously learned concepts and solidify their understanding.³³ For medical students, integrating technology into their learning increased their satisfaction with the course content and gave them the freedom of learning at their own pace.^{31,47,51,56,57,61} Another benefit of online learning is that it promoted collaboration among individuals from around the world to create an online platform that distributes clinical content.^{36,38,47,53,57} Some challenges of online teaching include technological hurdles, lack of face-to-face learning (which is not only considered critical for learning professional and clinical skills, but some cultures have a preference for face-to-face teaching), less engagement, and frequent distractions (this may be especially difficult for students who lack self-discipline).^{42,48,51} Additionally, synchronous learning may have not supported international students residing in areas with different time zones.⁴⁴ One of the major changes enforced due to the COVID-19 pandemic was virtual anatomy education.^{36,42,62} Dissection, which is considered the "gold standard" for learning human anatomy, is a privilege and honour for medical students to participate in.^{42,62} Although online teaching appears to be the most efficient method to comply with social distancing measures, transferring anatomy education to online platforms may pose significant challenges in ensuring respectful and ethical behaviour among students. Furthermore, online teaching can negatively impact students' abilities to conceptualize anatomical structures, given that hands-on learning constitutes a significant component of anatomy education.

Limitations and future directions

One of the limitations of our literature review was that our search criteria may have excluded some articles relevant to our review (e.g. insightful articles written in languages other than English). Another limitation of our review was that there was slight variation of some of the terminology among different countries. Non-standardized terminology may add ambiguity to the studied interventions, which in turn may lead to generating solutions that do not properly address the actual concerns. Additionally, many of the recommended interventions were provided by expert opinions rather than quantitative evidence. For example, there was a limited number of student surveys which quantified the success/failures of implemented interventions from the student perspective. With additional time to assess the interventions analyzed in this review and the emergence of new studies that communicate additional interventions, quantitative data will accumulate and provide stronger evidence for the outcomes of medical school interventions. In turn, this will provide a consensus on the efficacy of such suggested interventions. Another crucial element of an intervention is its sustainability. There is currently no evidence to predict when this pandemic will end. Thus, medical education will be forced to incessantly improve and adapt to the current situation.

Conclusion

This scoping review presents the implemented and suggested interventions for medical education during the COVID-19 pandemic from the current academic literature with the purpose of assisting medical institutions in evaluating the efficacy of various interventions prior to their possible implementation. The drastic public health measures executed rapidly invoked medical

education and associated organizations to arrange alternatives aimed at securing the progression of medical students and their education while simultaneously minimizing their risk of COVID-19 infection and spread. The incorporation of technology and remote learning into medical education has been persistently pursued and thus, due to the pandemic, the application of online medical learning strategies was expedited. The articles that discussed online alternatives (lectures, patient encounters, and exams) reported that while those interventions were suitable for the current global situation, they are unlikely to be sustainable due to the compromise in quality of education. Instead, incorporating an online aspect into a mainly physical medical education may be a preferable method. The accomplishment of stress management interventions for students was a thoughtful approach by medical institutions and would be an exceptional service if provided post-pandemic. The expedited entry of final year medical students on the frontlines while alleviating the healthcare burden would also increase the risk of infection and the risk of error due lack of adequate training. Some medical schools placed medical students into inter-professional groups or response teams allowing them to take part in the effort against the pandemic. A blend of both in-person and virtual rotations would be the safest way to approach clinical rotations to protect the students' health and provide clinical experience. The changes to the residency programs' application process include restricting the number of applications per applicant, delaying residency programs' access to applicant profiles, and hosting institutional virtual events to replace visiting sub-internships.

Disclaimers

The manuscript has not been previously published and is not under consideration in the same or substantially similar form in any other journal. All those listed as authors are qualified for authorship and order of authorship has been agreed upon by all members of the team.

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