


Impact of COVID-19 on Medical Education: A Narrative Review of Reports from Selected Countries

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ABSTRACT: The COVID-19 pandemic presented unprecedented challenges to medical training worldwide. Many studies examining barriers, such as student safety concerns and technological issues for adaptability to a virtual learning mode, were conducted during social distancing and described the pandemic's impact on medical education. This narrative sought to review how medical schools adapted to the pandemic and to provide a unique analysis of the challenges faced in delivering medical curricula worldwide. A search of the medical education literature yielded articles describing methods employed by medical colleges from locations worldwide. All articles that met search parameters were archived on PubMed. Of 109 manuscripts, 12 describe strategies adopted by 10 countries. They support the discussion of teaching and learning at the pre-clerkship and clerkship levels during the COVID-19 pandemic. Online learning became the method adopted by medical schools worldwide to address hurdles during the pandemic. Access to technology, the internet, and appropriate infrastructure, resulted in solid indicators of medical education success. From the student's perspective, the most significant advantage of this strategy was flexibility. The compiled reports are representative approaches used during the pandemic and may serve as guidelines for medical colleges when strategic change is needed during pre-clerkship and clerkship education. Strategies based on information technology proved successful; however, more equitable access is necessary. It is crucial to consider the complexities of syndemic conditions when adjusting the curriculum in challenging situations such as a pandemic.

KEYWORDS: Medical education, pre-clerkship, clerkship, COVID-19 pandemic, virtual curriculum, online, e-learning, worldwide, medical students' perceptions

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Introduction

The COVID-19 pandemic presented unprecedented challenges for individuals around the globe, including those training to fight it. Approximately 3 years after discovering the novel coronavirus, the COVID-19 pandemic continues to unfold. The disruption of the medical education system is just one example of the pandemic's influence on medical education, learning, and the transfer of a crucial knowledge base for future physicians. In medical schools, students were challenged to engage and succeed in a rigorous curriculum amidst the pandemic.¹ At the same time, administration and faculty were tasked with producing a class of educated professionals while following and staying updated on constantly changing protocols. Factors from safety concerns² for medical students exposed to COVID positive patients to technological challenges for those delivering a virtual curriculum called all normal procedures into question.^{3,4} Traditional face-to-face lecture-based delivery was no longer possible, and a lack of resources presented additional challenges for many.⁵

Before the COVID-19 pandemic, colleges had experience using flexible learning models, such as online learning, in medical school.^{6,7} Online learning platforms such as massive open online courses (MOOCs) on health and medicine topics have been incorporated into medical curricula for many years

and have grown significantly in the last 10 years.⁸ Institutions that had experience applying different learning modalities using information technology before the pandemic had a smoother, more rapid, and more effective transition to distance learning.⁹ Conversely, institutions that did not have adequate technology or infrastructure before the pandemic encountered multiple challenges.⁵

At the pandemic's start, approximately 2600 medical schools worldwide¹⁰ had to reorganize to sustain, remodel, and effectively deliver medical training throughout the crisis. The COVID-19 pandemic uniquely impacted colleges worldwide, with each school in its country of origin employing its own strategies for combating the disease and adapting medical education. This narrative review provides a unique analysis of the challenges and strategic changes that 10 medical schools around the world employed for pre-clerkship and clerkship medical education during the COVID-19 pandemic. We also highlight the effectiveness of strategies and differences in how students perceived them.

Methods

We initiated the literature review by searching PubMed, ScienceDirect, JSTOR, and Google Scholar databases. The strategy was designed to yield papers on change management



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in medical education during the COVID-19 outbreak and challenges in pre-clerkship and clerkship curriculum adaptations. Non-peer-reviewed journal articles were excluded from the analysis. Temporal limitations (2020–2022) were used to ensure the literature was relevant to COVID-19; no language restrictions were utilized. The search used the following keywords either alone or matched with Boolean operators “AND” or “OR”: *Medical education in COVID-19*; *Global medical education*; *E-learning during COVID-19*; *Online learning*; *Medical education in COVID-19 pandemic*; *Clerkship curriculum in COVID-19*; *Pre-clerkship curriculum in COVID-19*.

All manuscripts that met the parameters described above were those archived on PubMed. After removing duplicate results, 109 manuscripts were analyzed. The complete search strategy, including exclusion and inclusion criteria, is depicted in Figure 1.

The glossary in Table 1 defines the terms used by the educational institutions cited in this review. These terms/words were broadly applied in various contexts as medical education curricula were adjusted in response to the restrictions imposed by COVID-19.

Results

Twelve core articles were identified as representatives to report 10 countries' experiences (Table 2) and to support answering the central questions: “How has COVID-19 impacted medical education in different geographic areas?” and “How did the students perceive changes in the learning process that accompanied curriculum adjustments?”

Strategies to continue medical education during COVID-19

Table 2.

Strategies and quality of medical education for pre-clerkship and clerkship students

Successful strategies. Around the globe, many medical students felt that their colleges successfully used alternative learning programs and platforms during the pandemic. These medical schools employed curricula that included virtual platforms allowing student engagement with faculty, student-led learning, rounds, and streaming real-time procedures. In the opinion of students, the most significant perceived benefit of online teaching platforms was their flexibility.^{11,17,18,21,24}

From the student perspective, reports prior to the pandemic have indicated that online learning added value to the educational experience through supplemental videos, case-based learning, and question banks.²⁶ Under COVID-19, a cross-sectional online survey involving students from over 30 UK medical schools, 19.5% of students felt that online learning provided flexibility. This study also identified team-based/problem-based learning as a suitable format for delivery via online teaching platforms. This combination of pedagogical

methods allows students to digest information in their own time and discuss the material with peers.¹¹ Additionally, 19.8% of students felt online learning saved time spent traveling.¹¹ Faculty also expressed that technology supported flexible learning models such as online modules and flipped classroom instruction.^{11,12,27}

Students positively received the virtual curriculum at Chiba University in Japan.¹⁷ The school attempted to re-create the clerkship experience in a virtual setting to ensure student safety and protection from exposure to COVID-19.¹⁷ The curriculum included simulated electronic health records (sEHR) for inpatient visits, as well as electronic problem-based learning (e-PBL) and online virtual medical interviews (online-VM1) for outpatient visits. The three programs, sEHR, e-PBL, and online-VM1, were housed in an online simulated clinical practice (online-sCP) learning management system and an online meeting system facilitated by an overseeing physician. For sEHR, students reviewed and discussed the records using the online meeting system with a physician. During e-PBL sessions, students previewed simulated patients and discussed them on the learning management system. Online VMI allowed a faculty member to play the role of an outpatient while the student played the role of a physician. This was followed by a student-led discussion of their clinical reasoning in small groups over the online meeting system.¹⁷ After utilizing the virtual formats described above, Chiba University in Japan faculty surveyed students to collect quantitative and qualitative feedback on the new design.¹⁷ The quantitative data were collected using a seven-question survey comparing the online sCP to the previous curriculum. Students rated their experience as “acceptable” for all aspects of the new curriculum. Most students stated that the online sCP was more beneficial for learning approaches. Furthermore, e-PBL and online VMI scored higher than the traditional clerkship curriculum in learning organization and efficiency and writing medical summaries. All students surveyed indicated improved clinical performance after the online sCP in medical interviews and counseling. Even though the programs were not as effective in clinical performance as the traditional clerkship curriculum, they provided students with an adequate alternative to learning clinical skills during the pandemic.¹⁷

Data from the Republic of Korea provides further insight into online learning outcomes during medical school.¹⁸ Medical students from this school appreciated and welcomed most features of their online learning program. Students and professors rated the online curriculum at the end of each course. The most significant advantage for 70% of students and 35% of faculty was the flexibility to learn at any time and place, assuming an available internet connection. Additional strengths of online learning that were identified included: reviewing portions of the lecture multiple times, flexibility in the lecture sequence, and playing lessons at any speed. According to the ratings, students did not have difficulty

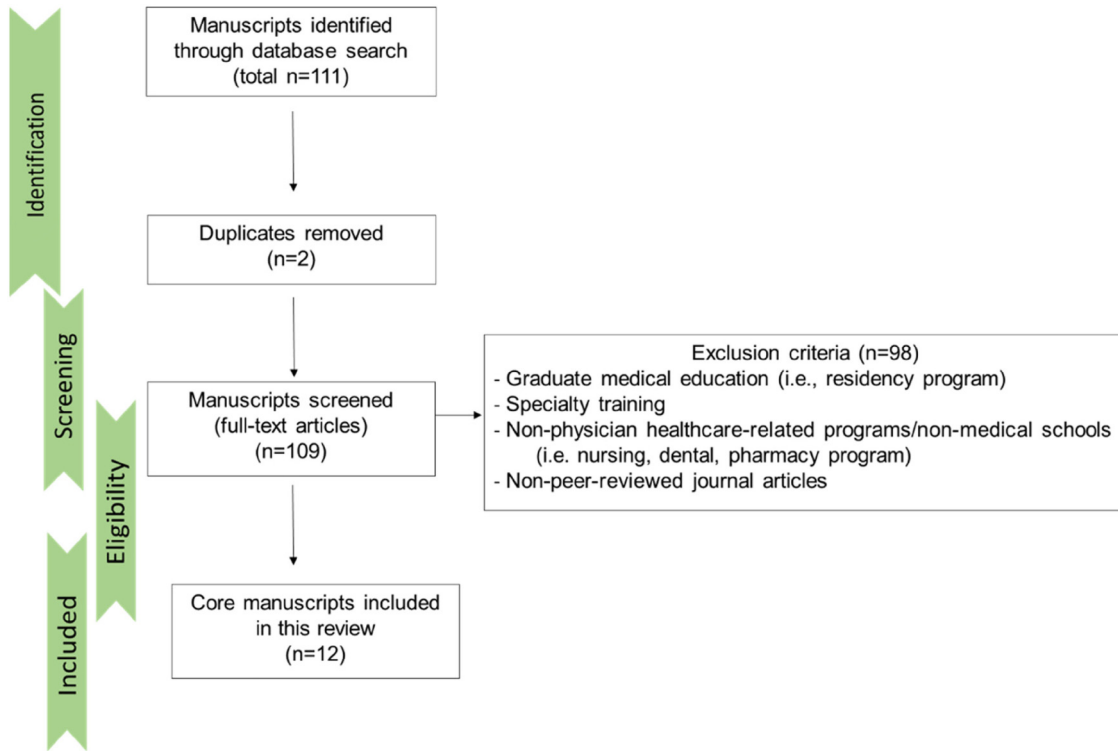


Figure 1. Database search strategy. Twelve articles were included to support answering the central questions: “How has COVID-19 impacted medical education in different geographic areas?” and “How did the students perceive changes in the learning process that accompanied curriculum adjustments?”

Table 1. Glossary of the terms: offline, online, and distance learning.

TERM	DEFINITIONS
Online learning	<ul style="list-style-type: none"> - Teaching and learning that is delivered via internet-based information systems. - Used interchangeably with internet-based learning and web-based learning. - Teaching sessions that cover key clinical conditions, case studies, and examination questions via live-streamed tutorials through video conferencing platforms.¹¹ - Interchangeable with live-virtual learning (can be considered a subset of online learning).^{12,13} - Teaching programs facilitated by platforms including video tutorials, online question banks, pre-recorded tutorials via their respective medical schools, and online flashcards.¹¹
Offline learning	- Traditional classroom learning. Teaching and learning take place at the same time and place. ⁷
Distance e-learning	- Using computer technology to deliver training, including technology-supported learning either online, offline, or both. ⁵

maintaining concentration or motivation for self-directed learning while engaging in online learning.¹⁸

In India, the AII India Institute of Medical Sciences (All India Institute) transitioned to a virtual curriculum at the beginning of the COVID-19 pandemic.²¹ Pre-clerkship and clerkship medical students, totaling 398 students, participated in the virtual curriculum. AII India Institute chose G-Suite for Education® as its primary platform. This platform combines

Google Classroom®, Google Meet®, and SMS messaging. The school utilized a four-hour teaching schedule, which included lectures, practical demonstrations, and case discussions. Faculty members implemented different methods to improve participation and collaboration and to mimic clinical scenarios, including encouraging students to use the chat box and turn on microphones. Faculty developed and reviewed a questionnaire to assess student perceptions of the online curriculum.²¹

The questionnaire assessed measures such as the ability of the students to ask the instructors questions regarding the material if the material shared during the virtual classes was helpful, and how the students felt about the interactions with faculty using the virtual platform. Approximately 92% of students believed the online format allowed for questions concerning material to be answered in real-time and considered the material shared during and after the virtual classes practical.²¹ These results suggest that the new methods provided student participation and engagement opportunities. In addition, nearly 56% of students believed the virtual classroom was either “as good as” or “better than” the physical classroom, which was attributed to increased interaction with their professors.²¹ The sentiments reported by the medical students demonstrate that specific strategies adopted by the virtual platform produced favorable outcomes. Although most students believed the virtual classroom offered further

Table 2. Locations and strategies to continue medical education during the COVID-19 pandemic.

COUNTRY/MEDICAL SCHOOL	STRATEGY	PRECLERKSHIP CURRICULUM	CLERKSHIP CURRICULUM	OTHER INFORMATION	CONCLUSION OF RESULTS
Africa, Makerere University.	Return to in-person clerkship curriculum.	None-limited data available		Undergraduate Program ³	The COVID-19 pandemic negatively impacted clinical learning.
United States, University of Washington School of Medicine	Virtual clerkship curriculum.	Years 1 and 2	Years 3 and 4	Undergraduate Program ^{13,14}	The virtual surgery curriculum should be presented at the beginning of the clerkship by the University faculty.
United States, Perelman School of Medicine at the University of Pennsylvania	Trial of virtual Otolaryngology-Head and Neck Surgery rotation.	Core 1 Year 1: Biomedical science, Integrated systems, and disease Year 2: Integrative systems and disease cont.	Core 2 Year 3: Clerkship Curriculum Core 3: Post-clerkship curriculum Individualized education.	Integrated Medicine Patient Care Transition (IMPACT): Four-year curriculum consisting of three cores organized around the science of medicine, the technology, and practice of medicine, professionalism, and humanism. ^{4,15}	Used first-person audiovisual technology to allow students to engage in procedures virtually.
United States, University of California San Francisco School of Medicine	Virtual Rounds Curriculum for Internal Medicine Clerkship.	Foundations 1: foundational knowledge in basic and clinical sciences	Foundations 2: immersion in a team-based clinical setting Career Launch: individualized curriculum based on student career goals.	Three-phase curriculum delivered over four years. ¹⁶	The use of virtual rounds for internal medicine clerkship rotations was viewed as effective by the students surveyed.
Japan, Chiba University's School of Medicine	Virtual clerkship curriculum.	Years 1, 2, 3, 4	Years 5 and 6	Graduate Program. ¹⁷	Students viewed online simulated clinical practice and electronic health records as beneficial for all clinical performance measures except medical interviews, physical exams, and humanistic qualities.
Jordan, University of Jordan, Jordan University of Science and Technology, Yarmouk University, Hashemite University, Mutah University, and Al-Balqa'a University.	Distance learning during clinical years.	Years 12,3	Years 4,5,6: typically a combination of theoretical lectures + seminars and in-hospital rotations	Six years of undergraduate medical education followed by post-graduate medical education in a specific specialty. ⁵	Distance learning is viewed as a solution for exceptional situations. Technical and infrastructural resources constitute a significant barrier to use outside of emergencies.
Republic of Korea, Seoul National University College of Medicine.	Online classes with an offline clinical clerkship.	Years 1,2: undergraduate education	Years 3,4: basic medical science Years 5,6: practical/clinical education	Six-year program that begins with undergraduate education and continues into the medical curriculum. ¹⁸	Students preferred the online courses offered during COVID-19 and wanted to maintain them after the end of the pandemic.
Pakistan, Pakistan Medical and Dental College.	E-learning.	Years 1–3: basic medical sciences	Years 4,5: clinical training in medicine, surgery, gynecology, pediatrics, ENT	Five-year undergraduate degree in "Bachelor in Medicine and Surgery." Followed by one year of dedicated clinical	Discusses the challenges low-income countries face when engaging in online medical education. These

(continued)

Table 2. Continued.

COUNTRY/MEDICAL SCHOOL	STRATEGY	PRECLERKSHIP CURRICULUM	CLERKSHIP CURRICULUM	OTHER INFORMATION	CONCLUSION OF RESULTS
			(Ear, Nose, Throat), and ophthalmology.	training (“house job”). ^{19,20}	include a lack of faculty training, internet connectivity issues, etc
India, All India Institute of Medical Sciences, Jodhpur, Rajasthan.	Global medical education in COVID-19; E-learning.	Semesters 1–2: Preclinical. Semesters 3–5: Paraclinical	Semesters 6–9: Clinical: Community medicine, medicine, and “allied subjects” (such as psychiatry, dermatology, etc.)	A 1-year internship follows training before trainees are allowed to practice independently. ²¹	Rapidly adopted the use of G Suite for online curriculum delivery. Students responded favorably to the method. However, half indicated a desire to return to the classroom.
Ireland, University College Dublin School of Medicine	Medical education COVID-19; Ireland medical education; online learning.	Years 1–3: Preclinical	Years 3–6: Clinical	Some medical schools limited preclinical to 1–2 years, leaving the remaining years dedicated to combining pre-clinical and clinical skills. Some schools award a BA in Medical Sciences after completion of preclinical. ^{22,23}	Medical students reported high-stress levels while attending medical school during the pandemic. There was an association between high-stress levels and the government and the university’s perceived crisis management.
United Kingdom, a pool of 39 medical schools.	Online teaching	Years 1, 2, and 3: Preclinical: Combination of lectures, practical classes, and supervisions.	Years 4,5 and 6: Clinical: in outpatient clinics and GP surgeries, supported by seminars, tutorials, and discussion groups	Completing the first three years leads to a BA degree. On completing the clinical studies in Cambridge, students are awarded two degrees, the Bachelor of Medicine and the Bachelor of Surgery (MB, BChir). ^{11,24}	The students perceived flexibility as the most significant benefit of online learning, a distraction from family members, and poor internet connectivity as the biggest challenges.
Libya, a pool of 13 medical schools	E-learning; Medical education.	Year 1: Intro subjects Year 2–5: Advanced sciences Year 6: Clinical subjects	Year 7: Clerkship curriculum with clinical rotations	The curriculum is followed by residency training; length varies based on specialty. ²⁵	Students viewed online learning favorably but faced challenges with implementation related to infrastructure and civil war.

opportunities to participate, 51% agreed that “physical classes are better than e-classes.”²¹ These findings demonstrate that although a virtual curriculum offers some benefits, half of the students still prefer in-person learning.

The Perelman School of Medicine at the University of Pennsylvania in the United States balanced safety with quality clinical exposure by developing an interactive virtual surgical rotation within the Department of Otorhinolaryngology-Head and Neck Surgery.¹⁵

Perelman School’s administration followed safety recommendations for surgical procedures during COVID-19.² The rotation consisted of interactive live-streamed surgeries, outpatient telehealth visits, and virtual small-group didactics. To provide the virtual operating room experience, surgeons wore

a head-mounted GoPro® camera that was streamed to a mobile device, and then screens were shared through a video conferencing platform. Telehealth® visits conducted through media such as BlueJeans® and Doximity® were organized such that consenting patients were interviewed by the medical student, who then discussed the case with the attending physician. Then the student and the physician joined the patient for a complete Telehealth® visit. Students also attended and had the opportunity to practice presenting patients during the virtual head and neck tumor board, virtual grand rounds, and resident didactics. Ultimately, it was found that students received more one-on-one time with attendings compared to a traditional learning model.¹⁵ The school recognized that this model only partially substitutes for an actual in-person

experience and that there are certain limitations to not physically experiencing the operating room, including the lack of development of technical skills. However, the virtual curriculum provided reasonable exposure to potential fields of interest while maintaining safety standards.¹⁵

Another example of an effective adaptation was a virtual rounds (VR) experience developed for clerkship students on their Internal Medicine rotation at the University of California San Francisco School of Medicine from April 23, 2020, to July 3, 2020.¹⁶ The goal of the VR experience was to provide students with a substitute for the clinical opportunities missed by engaging in online didactics, case studies, and simulations, including the skills of pre-rounding, oral presentations, diagnostic reasoning, and medical management discussions. The VR curriculum consisted of three components. The first was virtual pre-rounding. The second involved formulating a subjective, objective assessment, plan (SOAP) note and oral presentation, and then presenting their SOAP note to a VR small group who provided feedback. The third component was instructor-led clinical teaching. The VR module was offered three days a week for two weeks using videoconferencing. Students worked in teams of two third-year medical students, one Internal Medicine (IM) resident teaching assistant, one fourth-year medical student teaching assistant, and one hospitalist attending physician. After four blocks of students completed the VR curriculum, they were surveyed to determine the effectiveness of the experience. Of the 29 students who participated in the survey, 86% found that VR improved their pre-rounding skills, 93% reported improved presentation skills, and 62% enhanced clinical reasoning skills.¹⁶ In addition, all students found the small group discussions helpful. These results indicate that embedding VR modules in the curriculum can potentially educate clerkship students during future pandemics or supplement traditional in-person clerkship curricula.¹⁶

Unsuccessful strategies. Some of the same successful strategies in one place proved less successful in another due to factors such as lack of internet access, variations in socioeconomic conditions, political disarray, and technology limitations. Some schools did not implement substitute learning environments and continued with traditional clerkship and pre-clerkship curriculums throughout the pandemic. The institutions that continued with the conventional model of material delivery were generally received poorly by medical students.^{3,11,14,16,19,20,24,25}

For example, third and fifth-year medical clerkship students at Makerere University, Uganda, re-entered hospitals in October 2020. At that time, COVID-19 cases were rising rapidly in Uganda, which made medical students feel unsafe in their learning environment. When surveyed about their experiences, 81.7% of medical students felt at risk of contracting COVID-19 while participating in their Internal Medicine rotation.³ Additionally, over 66% of students believed it was challenging to follow the COVID-19 protocols put in place

by the hospitals, possibly leading to an increased risk of exposure. Another hindrance to clerkship students was combining junior and senior clerks for lessons and clinical assessments. Ultimately, these challenges discouraged about 12% of students from entering a career in Internal Medicine.³ The students' perceptions in this situation suggest that the adverse outcomes of an "unadjusted" curriculum during COVID-19 outweighed the positive aspects, leaving students with a relatively negative experience for their rotations.³

Less successful virtual clerkship was also experienced in schools from countries with well-developed infrastructure, such as the UK and the USA. For example, the University of Washington School of Medicine (USA) pulled all its clerkship students from clinical sites in March 2020 and switched the curriculum to a completely virtual setting.¹⁴ Virtual learning was conducted through online modules; however, these were challenging to provide for procedure-based rotations, like surgery and gynecology. These medical colleges in the USA reported challenges related to students taking the national board exams virtually compared to an in-person, proctored environment. Students completing the examination at home, which is sometimes a loud and uncontrolled environment, may need more proper technology. Because of the virtual environment, students missed two whole blocks of clerkship, leading to a condensed schedule for the rest of the clerkship once students were allowed back in the clinic. At the University of California San Francisco, fourth-year students relied on their elective rotations to improve their residency applications and obtain letters of recommendation, which is atypical.¹⁶ The decision to conduct clerkship virtually hindered the third and fourth-year medical students, leaving them with less clinical experience and a more challenging curriculum ahead.^{14,16}

In the UK, where Colleges of Medicine have well-developed infrastructure, they still experience difficulties delivering a virtual curriculum.^{11,24} Medical students from 39 UK medical schools reported family distractions ($\approx 27\%$) and poor internet connection ($\approx 22\%$) as the most common barriers to using online teaching platforms. For most UK medical students, acquiring clinical skills represented a relevant barrier to online teaching. About 76% said online education had not successfully replaced the clinical teaching they received via direct patient contact, and approximately 82% felt they could not learn practical clinical skills through online instruction.¹¹

In countries such as Jordan⁵ and Pakistan,^{19,20} infrastructure and technological barriers represented significant challenges to successfully implementing online medical education. Researchers in Jordan found that lack of proper infrastructure, technology, internet, and poor-quality connections posed challenges for medical students and faculty members. In addition, because distance learning had never been used in Jordan before the pandemic, the successful implementation of an online curriculum during the pandemic was limited by knowledge and/or training in online education, technology, and

applications. To address these challenges, the authors suggest collaborating with telecommunication companies to provide high-quality internet, professional development to improve instructors' technological skills, and unifying medical education platforms. While it was found that pre-clerkship medical education could be possible with improvements to technology and infrastructure, student results indicated that clinical involvement during clerkship years could not be effectively replicated through online programming.^{5,19}

Similar circumstances were encountered in Libya when many medical schools completely halted medical education at the pandemic's start.²⁵ Libya is currently experiencing a civil war and financial crisis, which has impacted its infrastructure and the ability of schools to continue operating. Placing students back in hospitals during the pandemic and ongoing civil crisis was impossible for many medical schools in the country. Some schools resumed in a virtual format, and research was conducted nationwide to determine the feasibility of virtual learning from the student's perspective. They found that many students had high technological proficiency and could use the appropriate technology to follow the education program; however, these studies indicated that many students suffered from anxiety (31%) and depression (10%).²⁵ Due to financial constraints, many students (78%) found it challenging to participate in e-learning. In addition, 66% of students reported that the political conflicts in Libya posed challenges to their e-learning.²⁵ Most respondents ($\approx 65\%$) disagreed that e-learning could be implemented easily in Libya. However, this may be related to the psychosocial impact of the lockdown imposed by the COVID-19 outbreak and the civil war.²⁵ This study highlights another critical factor when implementing virtual curricula: whether the curriculum will benefit or hinder students' mental health. They propose that social media could motivate junior medical students and increase peer-mentor interactions with trained senior students to mitigate the anxiety and stress endured during the COVID-19 pandemic.²⁵

University College Dublin School of Medicine (UCD) also found evidence of the influence of online learning on student stress.^{22,23} In the early phases of the pandemic, most medical schools in Ireland²² and the UK^{11,24} halted face-to-face instruction and opted for virtual curricula. To examine the relationship between online learning and student stress, UCD surveyed 200 medical students spanning all years whose demographics represented the student population. Using a combination of multiple dichotomous choices and Likert scale questions, three areas being investigated included level of stress, causes of stress, and institutional support. Regarding stress levels, 54.5% of students reported moderate or higher levels, with a more significant difference in women and international students.²² They found a positive relationship between levels of stress and the transition to online learning, online assessment formats, and personal and familial health concerns. Specifically, 66.7% of students reported moderate

stress or more caused by the transition to online learning, with 15.8% reporting "a great deal" of stress.²² It was found that students who reported higher stress levels expressed lower confidence in their government and institution's responses to the pandemic.²²

Discussion

This review highlighted the adjustments and innovative techniques adopted by medical schools worldwide during the pandemic. We examined the successes and challenges experienced by 10 countries. By comparing the effective and ineffective strategies in each of these countries, this review provides insight into best practices in medical education and practical ways to support medical students.

Some countries, such as the UK, Japan, India, and the US,^{11,15,17,21} could adapt quickly, while efforts of others, such as Libya,²⁵ Jordan,⁵ and Pakistan,¹⁹ proved less successful. The lack of resources mainly contributed to deficits in modifying the curriculum. As the pandemic's impact continues, it is essential to acknowledge gaps to be more prepared for future disruptions and support the continuity of medical education worldwide. Options include exploring the rapidly developing artificial intelligence (AI) technology as a resource for skillful humanistic health-machine interactions and to improve clinical decision-making. Although integrating AI into clinical practice routines unveils new challenges, there are examples of the appropriate use of AI in medical education.²⁸ Academic institutions worldwide are increasing their use of technology, in part due to the necessity imposed by COVID-19 restrictions. This use has pushed the development and innovation of these applications forward.²⁸

Students could continue their clerkship experience in a virtual format at medical schools in countries with well-established technological infrastructure. On the other hand, in countries lacking adequate internet, technology, and living spaces for pre-clerkship and clerkship students, students could not utilize the online curriculum to its fullest extent.

Over half of the clerkship students on internal medicine rotations in Uganda³ reported that clinical teaching should remain as it was in the pre-COVID-19 era. The authors reported concerns that e-learning might not facilitate clinical skills acquisition due to technological limitations. Importantly, this paper provided insight into the experience that students had in resource-limited settings to guide future faculty development.³

Medical schools in different geographic locations must adapt differently to future crises based on their access to resources. For example, although Libya and Dublin had very different realities, conclusions from those reports indicated that they might need to provide extra mental health resources for students while implementing various creative solutions that allow medical education to continue their education during a pandemic. Possible strategies include donating additional computers, textbooks, and other valuable items to students.^{22,25} For

medical schools like Pakistan and Jordan, continuing in-person learning with extra safety precautions for students and faculty may be more beneficial. Each medical school needs to view its unique situation critically, including individual student demographics and factors such as technology, infrastructure, political climate, and student home life.^{5,11} Further consideration of the impact that the COVID-19 pandemic has had on medical students' mental health is beyond the scope of this review. Reviews on medical students' mental health²⁹ and future career plans^{29,30} have been published elsewhere.

In addition to increasing pandemic preparedness, this review highlights the resilience and adaptability of the medical education system. The pandemic forced drastic changes in medical education curricula worldwide, some of which proved more efficient than pre-pandemic teaching and learning. For example, students in India agreed that their virtual classroom allowed them "increased flexibility, decreased travel time, and the ability to learn at their own pace."²¹ Some of the strategies viewed as favorable by students and faculty would also be beneficial in non-pandemic environments.

When deciding how to adjust clerkship curricula during a pandemic, there are multiple factors to consider for a successful transition. The data we accrued in this review indicate that not only technological resources and infrastructure are essential but also the level of infection within a community. Infection levels should be assessed before committing to an adjusted curriculum. For some programs, the severity and rate of infection within their communities were reliable and significant indicators to determine when students could safely return to hospitals and clinics during the pandemic.³¹

In Uganda, students entered hospitals around October 2020 while COVID-19 was still rising.³ Arranging for students to re-enter the hospitals during that time led to increased anxiety and apprehension.³ On the other hand, students in Washington State were not allowed to return to hospitals for reasons unclear to them,¹³ which negatively affected fourth-year students who planned on doing elective rotations and needed to build connections with those who could write recommendation letters. Depending on the level of COVID-19 infection, it may have been a wise decision to allow some Washington students to enter back into the hospitals to reach the goals they planned for their fourth year. Appropriate consideration of this factor could allow the administration to find a happy medium between providing students with safe work environments and allowing them to continue vital rotations.

Students struggled to connect to the internet in countries with underdeveloped technology³ and infrastructure or those undergoing economic or political crises.²⁵ Most were unfamiliar with virtual learning because it had not been extensively used. Locations like Libya may only be able to use one virtual platform at a time due to poor infrastructure from civil war.²⁵ In this situation, virtual platforms were unsuccessful and not an equal alternative to medical education provided in a non-

pandemic setting. On the other hand, in countries with well-established technology, internet, and infrastructure, the virtual platform worked well for students. At Chiba University in Japan, the various virtual platforms implemented gave students an adequate alternative to completing their clerkship rotations in person.¹⁷ Similar results were found at the All India Institute of Medical Sciences.²¹ Before an administration decides how to alter their clerkship education to adapt to a pandemic environment, they must evaluate their students' access to the internet and technology and the physical location where they will use these resources. Depending on their circumstances, students may be unable to use the internet or do not have the appropriate device. In that case, a virtual platform will not provide a similar educational experience to the typical clerkship years. A virtual setting may be an adequate solution if students have this access and technology. Access to technology, the internet, and the appropriate infrastructure are strong indicators of success for the virtual educational platforms used during the COVID-19 pandemic.

Another indicator of success is the impact of the curriculum on student mental health. The University College Dublin School of Medicine study described the negative impact that the pandemic has on student stress levels due to various reasons. The authors specifically reported stress levels caused by the transition to an online curriculum during the pandemic.²² Considering the points raised in this review, recommendations for addressing stress levels during transitions include communication with students, connecting with those identified as populations disproportionately impacted by the changes, and incorporating resilience training into early medical education curricula.

Hope can be found on the premise that substantial medical advances have been made during difficult times. The COVID-19 pandemic has allowed students and educators to adopt new practices and principles. Ultimately, the pandemic has limited the clinical exposure for clerkship students. However, there is an opportunity to identify areas where medical education can adapt to provide opportunities outside traditional clinical settings.

Exposing students to clinical settings early in their education is an important component of medical training; reproducing it in adjusted curricula is essential. During the pandemic, healthcare professionals had to adapt quickly to caring for many patients with limited resources as COVID-19 infections grew. Preparedness, adaptability, and crisis intervention protocols require real-world experience. In this sense, practical guidance elaborated by an educator from the Perelman School of Medicine at the University of Pennsylvania medical schools indicates a need to adopt sustainable methods to preserve the integrity of clerkship curricula.¹⁵ These methods allow educators to ensure student and patient safety while continuing clinical exposure and include "consolidating and moving clinical, didactic sessions online earlier to allow for later entry into the

clinical environment; creating and using available virtual cases; modifying the academic calendar to exchange later experiences (eg, scholarly work) and defer clinical rotations; and involving students in the telehealth environment, including electives based on experiences students are pursuing to enable them to assist and learn in this critical situation.”⁴

The Virtual Rounds model employed at the University of California San Francisco School of Medicine¹⁶ and the surgical elective at Perelman School of Medicine at the University of Pennsylvania¹⁵ are examples of models that have the potential to provide students with the exposure and skills that a clerkship rotation offers. These models included streaming procedures, virtual small group discussions, virtual rounds that include individuals at different levels of medical training, and integrating student involvement in telehealth visits. The success of these techniques highlights the power of having infrastructure and technology in place before the onset of the pandemic. With a reliable internet connection and access to resources such as GoPro® cameras and specific software, students could bring the clinical experience into their everyday lives without entering the clinical setting. Technological advances and reliable infrastructure in the United States allowed these two institutions to provide baseline educational opportunities and adapt clinical models to substitute for the inaccessible clinical setting.

The manuscript is not without limitations. We compared successful and unsuccessful tactics different institutions used to adjust medical education during the COVID-19 outbreak, particularly transitions to online teaching. For this purpose, individual projects of single institutions across the globe were selected based on their respective research questions. Still, they may not represent the experience of an entire country or may not consider a country’s systemic problems. In addition, data were extracted from designated literature reports that describe studies with different designs, most of which were based on data collected through electronic surveys or did not have previously standardized and validated tools to assess clinical learning experience during this COVID-19.

Conclusion

The COVID-19 pandemic has disrupted medical education, necessitating quick student, faculty, and administration adaptations. It has exposed curricula and education delivery gaps, particularly in preparing students with historically excluded backgrounds. Students’ firsthand experience has prepared them to embrace innovative and comprehensive approaches to healthcare learning. The data compiled herein serve as guidelines for colleges making changes during different stages of medical education. Recommendations cannot be one size fits all, as indicated by the experiences of various schools. However, as a take-home message, points of consideration that could guide global actions are:

- it is crucial to consider the complexities of syndemic conditions while adjusting the curriculum in response to challenges such as a pandemic;
- disciplines prioritizing health equity and crisis management are underscored;
- information technology and enhancing inclusivity go hand-in-hand;
- online learning provided flexibility and was learner-oriented;
- equitable technology access and enhancing internet provision are challenges to be tackled.

Authors’ Contribution

CR conceived the project and coordinated manuscript production. CR, MF, MM, LB, and NS conducted the literature search. CR, MF, MM, LB, and NS contributed equally to the manuscript. CR edited the final version. CR, MF, MM, LB, and NS critically revised and approved the manuscript’s final version. CR, MF, MM, LB, and NS are responsible for publishing the final version’s intellectual content.

Ethical Consent

Not applicable.

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