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Changes in undergraduate medical education due to COVID-19: a systematic review

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Abstract. – OBJECTIVE: This study aims to provide medical educators with insights into the current status and prospects of undergraduate medical education, which has been affected by the COVID-19 pandemic.

MATERIALS AND METHODS: We conducted a database search of PubMed, Embase, and ERIC and identified articles on COVID-19-related undergraduate medical education. We independently reviewed titles and abstracts and extracted data on the geographic location of the study, area of specialty, phase in medical school (preclinical year, clerkship year, etc.), type of paper, and the main content of the study.

RESULTS: A total of 49 articles published across multiple countries were included in this study. These were categorized as dealing with either (1) curriculum changes in undergraduate medical education due to COVID-19 or (2) student-led educational activities related to COVID-19. The 41 articles in the first category showed two main trends: replacing in-person lectures with online classes in the preclinical years and adopting various remote educational methods to compensate for the discontinued or truncated clerkship in the clinical years. The eight articles in the second category showcased various student educational activities that were conducted to meet the public's medical needs during the pandemic.

CONCLUSIONS: This review summarized the essential changes in undergraduate medical education worldwide and reflected on the various teaching methods adopted by medical schools. In preparation for the post-COVID era, a comprehensive online curriculum and evaluation tools are needed, which require the development of necessary infrastructure and adequate resources. Education aimed at helping students be more socially aware and responsible as medical professionals must be promoted.

Key Words:
COVID-19, Systematic review, Undergraduate medical education.

Introduction

The unprecedented rate at which COVID-19 spread worldwide, as well as its scale of reach and the prolonged duration of the pandemic, was unexpected. This new, highly contagious disease moved rapidly across China and spread to more than 200 countries, infecting over 130 million people by April 2021[1]. The strong contagion and high mortality rate of COVID-19 have disabled the world because of national and international lockdowns that had to be enforced in most of the affected countries. The COVID-19 pandemic severely limited in-person interactions and social activities, and greatly impacted the educational system. Educational institutions worldwide have been unable to provide their standard educational curriculum. According to a UNESCO report,

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in April 2020, a total of 1,578,657,884 learners in 190 countries were unable to attend school, constituting 90.2% of the total enrolled learners[2]. The pandemic prevented most students from attending in-person classrooms, and medical schools had to find ways to transform and continue undergraduate medical education. Social distancing measures precluded medical students from attending classroom-based teaching and discussions[3]. Most schools switched from in-person classroom lectures to online lectures to continue medical education. Faced with such an unexpected change, medical educators have published various reports on the current medical education situation globally. To adapt to this rapid change, a comprehensive study on these published articles is needed. However, existing systematic reviews on medical education in the background of COVID-19 are either too broad, encompassing undergraduate, graduate, and continuing medical education, or limited to only surgical education[4,5]. Therefore, we undertook a systematic review to assist medical educators across the globe in formulating ideas for devising a more effective undergraduate medical education (UME) during periods of disruption (e.g., when social distancing has to be practiced). We aimed to answer two research questions: 1) What are the COVID-19-related curriculum changes in UME? 2) What are the COVID-19-related educational activities led by undergraduate medical students? Ultimately, we hope that this review provides medical educators with insight into the current status and prospects of UME, which has been severely affected by the COVID-19 pandemic.

Materials and Methods

Search Strategy

The search included three electronic databases: PubMed (Medline via PubMed), Embase, and Educational Resources Information Center (ERIC). For the PubMed search, the search Boolean was (Medical education OR "education, medical" [MeSH Terms]) AND ("coronavirus" [MeSH Terms] OR "coronavirus" [All Fields] OR "COVID 19" [All Fields] OR "severe acute respiratory syndrome coronavirus 2" [Supplementary Concept]). For other databases, the search terms were "Medical education/exp" OR "medical education" AND "COVID-19/exp" OR "COVID-19." To broaden the scope of the literature review and cover papers that may have been missed using the database searches, key journals such as Academic Medicine, Medical Education, BMC Medical Education, and Medical Teacher were hand-searched. The literature search was completed on June 8, 2020.

Inclusion and Exclusion Criteria

All publications were manually sorted on the basis of the inclusion and exclusion criteria. We included studies on planned, current, or completed COVID-19-related education carried out either by the school or by the students themselves in UME. We included studies on UME at all years and encompassing all specialties. We excluded studies that were not directly related to education, such as admission, safety, mental healthcare of medical students, and non-education-related student activities. Studies not available in English were also excluded. Two authors independently reviewed the titles and abstracts of all articles against the inclusion and exclusion criteria. When the authors disagreed on article eligibility or when information in the abstract was insufficient or absent, the whole article was reviewed. The authors screened the entire data to remove studies conducted outside of medical education (e.g., those in pharmaceutical, nursing, or dental education).

Data Extraction

Every article included for review was downloaded and read in full. The following data were extracted from each article: (1) country of study, (2) area of specialty, (3) phase of UME, (4) type of publication, and (5) main content of the publication.

Data Analysis

A descriptive analysis was conducted on the extracted data. Two authors independently summarized the characteristics of each study on the basis of the five aforementioned categories. Summaries by each author were reviewed together, and occasional differences in the main contents were resolved through consensus. We were unable to conduct a meta-analysis because of the heterogenous nature of the included articles.

Results

A flowchart of the study selection process is provided in Figure 1. The initial search yielded 1,612 results; after removing the duplicates, 961

articles were retained. A few additional articles were found through hand searches and were added to the dataset. Two authors independently reviewed the titles and abstracts of these articles (n = 979). We deemed 909 of those articles irrelevant, as most were either not concerned with UME or were irrelevant. Two authors reviewed full texts of the remaining articles (n = 70) to remove those unrelated to undergraduate level or that had student activities unrelated to education. We resolved the differences in opinion regarding data extraction through consensus. Finally, 49 articles were identified for inclusion in the final dataset. A complete list of the literature included in this review is available online (**Appendix 1**).

Classification of Published Studies on COVID-19-Related Medical Education

The studies included in this review represented geographical locations worldwide, reflecting the global impact of the COVID-19 pandemic. As illustrated in Table I, most studies were conducted in the United States (32.7%), followed by the UK (20.4%), Canada (8.2%), Singapore (6.1%), Australia and New Zealand (6.1%), and Iran (6.1%). Other articles were published in China, India, Italy, Switzerland, Denmark, France, Hong Kong, Brazil, Egypt, and Cameroon.

Of the 49 articles, 15 (30.6%) were related to specific medical specialties divided into three fields: basic science (10.2%), clinical science (16.3%), and health systems science (4.1%). Basic sciences included articles on anatomy and genetics. Clinical sciences included three articles on surgery and two on neuroscience. There was one article each on orthopedics, dermatology, and ophthalmology. Most of these articles described changes in the curriculum due to COVID-19. There were two articles on health systems science. The remaining 38 (69.4%) articles were not specific to any medical specialty.

Our study encompassed all four years of medical school. Of the 49 articles, 13 (26.5%) focused on students in preclinical years (Years 1 and 2) and 26 (53.1%) on students in clerkship years (Years 3 and 4). Ten (20.4%) articles either included students of all years in UME or did not specify the grade. While articles on preclinical years described a curriculum change from in-person to online classes, those on clerkship years presented creative methods of replicating

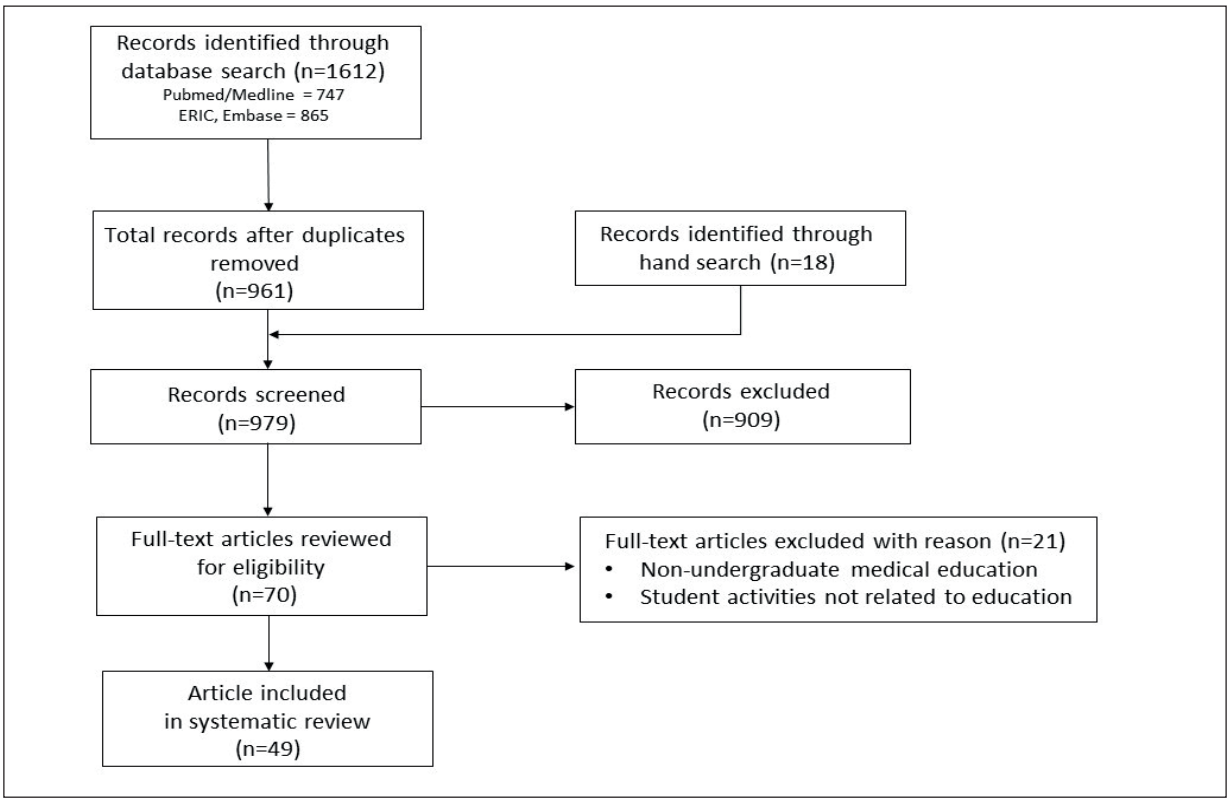

Figure 1. Flowchart of data collection and study selection processes in systematic review.

Table I. Characteristics of included articles.

Characteristic	N (%)
Country	49 (100%)
North America: USA (16)*, Canada (4)	20 (40.8%)
Europe: UK (10), Italy (1), Switzerland (1), Denmark (1), France (1)	14 (28.6%)
Asia: Singapore (3), Iran (3), India (2), China (1), Hongkong (1)	9 (18.4%)
Etc.: Australia & New Zealand (3), Brazil (1), Egypt (1), Cameroon (1)	6 (12.2%)
Specialty	49 (100%)
Basic sciences: Anatomy (4), Genetics (1)	5 (10.2%)
Clinical sciences: Surgery (3), Neurosurgery (2), Orthopedics (1), Dermatology (1), Ophthalmology (1)	8 (16.3%)
Health systems science	2 (4.1%)
Not specified	34 (69.4%)
Phase	49 (100%)
Preclinical years	13 (26.5%)
Clerkship years	26 (53.1%)
Entire period	9 (18.4%)
Not specified	1 (2.0%)
Publication type	49 (100%)
Commentaries (commentary, viewpoint, opinion, editorial comment, perspective, insight)	21 (42.9%)
Letter	10 (20.4%)
Editorial	7 (14.3%)
Review	5 (10.2%)
Research	3 (6.1%)
Correspondence	2 (4.1%)
Description	1 (2.0%)

*(): number of articles.

clinical practice owing to the discontinuation of clerkship.

The following types of articles were included: commentaries (n=21), letters (n=10), editorials (n=7), review articles (n=5), research articles (n=3), correspondence (n=2), and a descriptive article (n=1). We did not identify articles that used credible evaluation index, descriptive statistics, or controlled study designs.

Changes in Medical Education

The articles were categorized according to the following typology:

1. Curriculum changes in UME due to COVID-19: publications predominantly centered around descriptions of UME curriculum changes and situations related to COVID-19.
2. Student-led educational activities related to COVID-19: publications predominantly centered around descriptions on planned, current, or completed COVID-19-related student-led educational activities in UME.

Curriculum Changes in UME due to COVID-19

A total of 41 (83.7%) articles described specific curriculum changes in UME (Table II). Among them, 13 (26.5%) catered to UME curriculum changes for students in preclinical years. They mainly focused on the transition from in-person lectures to online lectures[6-18]. A study by the National University of Singapore explored the establishment of the "COVID-19 response team" in academic medical centers to manage the pandemic and detailed the process of leveraging remote education[8]. Six preclinical articles reported switching to online lectures for specific subjects such as anatomy, genetics, or ophthalmology[9-13,17]. One study reported ten universities in Australia and New Zealand that conducted courses in anatomy online and specifically included the instructors' feedback on the online anatomy education[10]. An institution in the United States used Zoom to help students identify abnormal dysmorphology cases in their online genetics course, using the chat function to allow students to compete with each other[12]. A study in Hong Kong introduced Zoom-based small group tutorials on ophthalmic education[13]. Most online lectures took the form of webinars, online conferences, small group discussions using well-known digital platforms such as Zoom, Google Hangouts, and Webex. Other articles described utilizing online technology to practice team-based learning (TBL)[14] and flipped learning (FL)[15], in addition to simply using it as a source of lecture deliverance. One article re-

Table II. Curriculum changes in undergraduate medical education due to COVID-19.

Main content	Specific examples [Reference number]
Preclinical education (n = 13)	
Online transition process	[6, 7, 8, 18]
Transition to online learning in specific subjects	Anatomy [9, 10, 11, 17], Genetics [12], Ophthalmology [13]
Methods for online education	Team-based learning [14], Flipped learning [15]
Assessment	Open-book examination [16]
Clinical clerkship education (n = 24)	
Online transition process	[19, 20, 21, 22, 23, 24, 25, 26, 27]
Transition to online clinical practice in specific subjects	Surgery [28, 29, 30], Neurosurgery [31, 33], Orthopedics [32], Dermatology [34]
Methods for online clinical practice	Virtual bedside teaching [35], telemedicine technologies [36], Using Zoom to meet SP [37], Video conferencing [38], Virtual morning report [39]
Assessment	Open-book examination [40, 41] OSCE [42]
Others (n = 4)	
Online conversion experience	[43, 44, 45]
Faculty development for online small group teaching	[46]

OSCE: Objective Structured Clinical Examination.

ported open-book examination as an assessment method[16].

Of the 41 articles that described specific curriculum changes in UME, 24 (49.0%) were related to clinical years. Nine of them described the online transition process for both courses and clinical practices[19-27]. Seven articles described subject-specific curriculum changes[28-34]. Discontinuation of in-person clinical lessons by the surgery department was compensated through videoconferences on clinical and anatomy lessons using Google Hangouts[30]. Emory University employed teleconferencing as a component of surgical clerkship, through which they discussed clinical cases and guided students with curated surgical videos of selected neurosurgical procedures[31]. Furthermore, a risk-free clerkship setting generated by simulation-based orthopedic surgery was introduced[32]. One article explained the online neurosurgery curriculum, highlighting the need for an alliance between schools because of the lack of online teaching sources in Africa[33]. Five articles explored various teaching methods to compensate for students' missed experiences due to suspended clerkship. The UC Irvine School of Medicine implemented virtual bedside teaching rounds, in which an attending physician ran a videoconferencing application on an iPad pro affixed to a computer on wheels. This method was successful, as 92.9% of the students strongly agreed that they had felt engaged and would like to continue participating in virtual COVID rounds[35]. Two articles reported using telemedicine technologies or Zoom to meet standardized patient (SP) encounters[36,37], and two other articles described using videoconferencing or implementing a multi-organization online model, called "virtual morning report"[38,39]. Three articles described assessment methods, including the open-book examination and the Objective Structured Clinical Examination (OSCE)[40-42].

Three articles described the students' experience with online conversion for all years in UME, and one article reported faculty development for online small group teaching[43-46]. Overall, most articles discussed the urgent need to implement a new education method due to time constraints, poor technical skills, inadequate infrastructure, and the absence of institutional strategies[10,43,44].

Student-Led Educational Activities Related to COVID-19

Of the 49 articles selected for the study, eight (16.3%) were related to student-driven activities in UME during COVID-19 (Table III). More than 700 medical students from the University of Birmingham volunteered to support the National Health Service in the UK[47]. In Switzerland, the student-based Corona Task Force established a trained swab team, with volunteers at the front-line performing diagnostic swab testing[48]. These two articles on student-led volunteer teams demonstrated a novel form of clinical practice invol-

Table III. Student-led educational activities related to COVID-19.

Main content	Reference number
Student-led volunteer team	[47, 48]
COVID-19 Medical Student Response Team (MSRT)	[49, 50]
Create online initiatives	[51, 52]
Student-led peer-mentoring program	[53]
Produce a weekly newsletter	[54]

ving medical students at the scene in response to the pandemic.

Student leaders at Harvard Medical School created a COVID-19 Medical Student Response Team (MSRT), in which over 500 students participated and shared their organizational framework with other medical schools across the country. The framework consisted of four virtual committees—Education of the Medical Community, Education for the Broader Community, Activism for Clinical Support, and Community Activism—with the aim to identify evolving needs between administration, hospitals, and students[49]. Medical students of The University of British Columbia created an MSRT and engaged over 700 student volunteers[50].

In Brazil, students initiated an online public health website for EpiServ (Epidemiology and Health Services Observatory) to increase public understanding of the disease by updating epidemiology bulletins with the most recent research results[51]. Similar initiatives have been reported from the UK[52]. Senior medical students in Iran, trained by the faculty for 40 hours in teaching and learning methods, communication skills, and effective consulting techniques, formed a peer-mentoring social media platform[53]. They exchanged thoughts, feelings, and knowledge with 371 underclassmen on anxiety and stress due to the COVID-19 pandemic. Further, students at a medical school in Canada created a weekly newsletter that directly responded to questions on COVID-19[54].

Discussion

Most articles described curriculum changes as a measure of coping with the current situation. As face-to-face interactions have been suspended in medical schools, most schools continued their preclinical curriculum by switching to online delivery but discontinued or shortened the clerkship period for the clinical years. The introduction of various teaching methods as a countermeasure, showcased by numerous articles published since the outbreak, reflects medical schools' global efforts to overcome teaching restrictions due to the COVID-19 pandemic.

In reality, however, students have experienced the shortcomings of online learning and the inability to communicate and personally interact with professors and patients in their medical education courses. For instance, the prevailing view in many articles was that virtual clerkship could not replace physically seeing and interacting with patients[13,17,31,34,36,42]. Additionally, 53% of the students expressed that remote OSCE was less effective than in-person OSCE for clinical skill assessment[42]. Therefore, medical educators have been deeply interested in devising new strategies to overcome the shortcomings of online lectures and limited remote clerkship. Particularly, for online courses, introduction of TBL and FL components into online lectures significantly increased student participation and improved their self-directed learning[8,14,15]. Components of TBL and FL are crucial during and after the pandemic, as they refine the students' ability to effectively search and proactively seek for appropriate solutions rather than being simply instructed to memorize and repeat given information. In this regard, integration of TBL and FL classes into the online UME curriculum using information and communication technology (ICT) can contribute to effective education that promotes student participation and self-directed learning in this era of limited face-to-face lectures.

For clinical practice, it is necessary to recognize that virtual clerkship cannot replace hands-on clinical practices and interactions in terms of the skills obtained. Pre-learning materials such as recorded lecture videos or texts must be provided to maximize student understanding before the virtual rounds. A communication system allowing effective interaction between students, patients, and professors is needed.

In addition to appropriate modifications to the existing curricula, various systems should be

established to support this environment[55], such as an educational curriculum support system and necessary infrastructure to aid in its effective implementation. Systematic evaluation tools must be developed, as the current design of such tools for online lectures is insufficient[9,11,43].

We also highlight the importance of educational alliances between schools[33]. With the development of ICT, students can view lectures from world-class experts without attending their university. The COVID-19 pandemic has given rise to an ICT-based curriculum at an age when knowledge is crossing the boundaries of universities and expanding the time and space for education. An educational alliance between schools can effectively resolve the inequality between schools and overcome the limitations of each school's resources. This educational alliance will allow each school to maintain its originality and identity while freely sharing its educational resources, enabling quality education with fewer resources.

Through this study, we found that medical students worldwide are creating voluntary initiatives related to COVID-19, as the pandemic enabled medical professionals and medical students to reflect on their medical professionalism. Students trying to help solve the COVID-19 situation through various initiatives emphasize the need for an education that nurtures medical students as socially responsible professionals in the field of medicine.

We also found that healthcare systems worldwide were exposed to various problems due to the COVID-19 pandemic. The need for practical training on adequate utilization of capabilities within the limited resources of the national health care system, rather than simply developing medical knowledge and skill, became evident. Several studies highlight the importance of public health and the need for health systems science[56,57]. Global health education is becoming an essential part of medical education, especially as barriers between countries are breaking down. With a globally focused education, specialized training in responding to emergencies or natural disasters, communication skills as medical professionals, and leadership skills in effectively leading a team is required. Finally, students need an education that allows them to creatively understand the health system and overcome the current limitations.

Limitations

This study was conducted to investigate changes in UME due to COVID-19; however, it was found that most studies described the early stages of changes related to COVID-19 and experimental or control studies that provide accurate observation and analysis had not been conducted. Not enough time has passed for a paper demonstrating the objective effects of the rapidly changing medical curricula to be published. Thus, proving the short- and long-term effects of the transformed curricula referred to in the reviewed literature has its limitations. Therefore, further studies must be conducted to report the new UME curriculum based on objective outcomes and evaluation. Furthermore, a systematic review that comprehensively covers these well-constructed curricula is also needed. Nonetheless, our study is significant in that it examines the overall flow of the rapid modifications to UME globally and provides ideas to respond to various situations.

Conclusions

Medical education has been interrupted by COVID-19. Medical schools have begun transitioning to online lectures and implementing new teaching methods using technology to accommodate remote clerkship practicals to overcome this situation. Medical students are also actively devising strategies to deal with the situation. In preparation for the post-COVID era, we must develop a solid online curriculum and effective evaluation tools. We must establish appropriate infrastructure and prepare adequate resources to aid in its effective implementation. We must also educate students to assume social responsibility as medical professionals.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Authors' Contribution

SA and JIS designed the study; IRL and HWK collected the data, and IRL, HWK, and SA conducted the analysis. IRL, HWK, YL, AK, LJ, LS, and JIS wrote the first draft of the manuscript. All authors had full access to the study data. All authors reviewed, wrote, and approved the final version.

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