What is The Impact of The COVID-19 Pandemic on Residency Training: A Systematic Review and Analysis

Shang-Kai Hung (✉ mm200411800@cgmh.org.tw)

Linkou Chang Gung Memorial Hospital

Shou-Yen Chen

Linkou Chang Gung Memorial Hospital

Hsiang-Yun Lo

Linkou Chang Gung Memorial Hospital

Research Article

Keywords: COVID19, residency training, residents, medical education

Posted Date: April 14th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-400264/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Background

The coronavirus disease 2019 (COVID-19) pandemic has greatly affected medical education in addition to clinical systems. Residency training has probably been the most affected aspect of medical education during the pandemic, and research on this topic is crucial for educators and clinical teachers. The aim of this study was to understand the effect of the COVID-19 pandemic comprehensively through a systematic review and analysis of related published articles.

Methods

A systematic review was conducted based on a predesigned protocol. We searched MEDLINE and EMBASE databases until November 30, 2020, for eligible articles. Two independent reviewers extracted data by using a customized form to record crucial information, and any conflicts between the two reviewers were resolved through discussion with another independent reviewer. The aggregated data were summarized and analyzed.

Results

In total, 53 original articles that investigated the effect of the COVID-19 pandemic on residency training were included. Studies from various regions were included in the research, with the largest percentage from the United States ($n = 25$, 47.2%). Most of these original articles were questionnaire-based studies ($n = 44$, 83%), and the research target groups included residents (79.55%), program directors (13.64%), or both (6.82%). The majority of the articles ($n = 37$, 84.0%) were published in countries severely affected by the pandemic. Surgery ($n = 36$, 67.92%) was the most commonly studied field.

Conclusions

The COVID-19 pandemic has greatly affected residency training globally, particularly surgical and interventional medical fields. Decreased clinical experience, reduced case volume, and disrupted education activities are major concerns. Further studies should be conducted with a focus on the learning outcomes of residency training during the pandemic and the effectiveness of assisted teaching methods.

Background

The coronavirus disease 2019 (COVID-19) pandemic has greatly affected every facet of the health care system since COVID-19 was first identified in Wuhan, China, in December 2019. The pandemic overwhelmed health care systems rapidly in many countries, and numerous studies have investigated the clinical effects of the pandemic (1–5). The COVID-19 pandemic has not only damaged clinical systems but also affected medical education severely. However, research on the effect of the COVID-19 pandemic on education is as-yet limited.

When considering medical education, residency training has probably been the most affected during the COVID-19 pandemic because the core of residency training is clinical experience and clinical skill proficiency, which have been reduced because of multiple factors in the pandemic. Dedeilia et al. published a systematic review on educational challenges in the COVID-19 era and revealed that both medical and surgical education have been severely affected

(6). However, the article was published in the early stage of the pandemic when literature on the topic was limited, and the focus of the research was not only residency training but also medical students' education. Additionally, most of the included articles were nonoriginal manuscripts and may have been insufficient to analyze the effect of the COVID-19 pandemic on residency training.

Understanding the influence of the pandemic on residency training is crucial to being able to adopt methods to maintain consistency in training quality. The aim of this study was to identify the real effect of the COVID-19 pandemic on residency training through a systematic review of relevant published articles and further analysis of the results. Our study may help residency training program directors worldwide to comprehensively understand the influence of the pandemic and adopt assisted teaching methods to provide effective training.

Methods

Systematic review protocol

A systematic review was conducted based on a predesigned protocol in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (7).

Search strategy

We searched the MEDLINE and EMBASE databases for eligible articles until November 30, 2020 (for approximately 1 year from the commencement of the COVID-19 pandemic). The search strategy was based on the following algorithm: ("COVID- 19" [All Fields] OR "COVID-2019" [All Fields] OR "severe acute respiratory syndrome coronavirus 2" [Supplementary Concept] OR "severe acute respiratory syndrome coronavirus 2" [All Fields] OR "2019-nCoV" [All Fields] OR "SARS-CoV-2" [All Fields] OR "2019nCoV" [All Fields] OR ("Wuhan" [All Fields] AND ("coronavirus" [MeSH Terms] OR "coronavirus" [All Fields]))) AND ("education, medical" [MeSH Terms] OR ("education" [All Fields] AND "medical" [All Fields]) OR "medical education" [All Fields] OR "resident training" [All Fields] OR "trainee" [All Fields]).

Inclusion and exclusion criteria

We aimed to include all original articles discussing the effect of COVID-19 on residency training in different specialties. Furthermore, we only included studies that were published in English. We excluded nonoriginal articles, such as reviews, editorials, perspectives, short or special communications, and letters to editors. Studies regarding medical students or paramedical specialties, such as dentistry or nursing, were excluded. Moreover, studies focused on methodologies or technological innovations rather than residency training were excluded.

Study selection and data extraction

Figure 1 depicts the study selection and review processes. After selecting articles from two databases, we removed duplicate articles manually. Two independent reviewers (SKH and HYL) scanned the title and abstract of all articles to determine relevancy in light of the inclusion/exclusion criteria. Articles without abstracts were included for full-text assessment and evaluated at that stage. Two reviewers shared their results after scanning the title and abstract of all articles, and only articles that were excluded by both reviewers were eliminated from further full-text assessment. During the full-text assessment stage, we used a customized Excel sheet to record essential information of the article. Article type, first author of the article, training specialties, publication date, target group, and country of the enrolled population were extracted. Then, two reviewers evaluated the extracted full-text articles separately according to the criteria. Any conflicts between the two reviewers regarding the extracted articles were resolved through discussion with another reviewer (SYC). The included articles were further quantitatively analyzed or described narratively.

Statistical analysis

Descriptive statistics of aggregated data are presented using count and proportions. Descriptive analysis was performed according to publication date, country, and specialty separately. Further subanalysis was performed based on study content, geographic location, pandemic severity, and specialty category. Pandemic severity was defined according to the World Health Organization dashboard (8). Statistical analysis was performed using Microsoft Excel (2016, Microsoft Corporation, Seattle, Washington).

Results

The search yielded 3581 and 2567 articles from MEDLINE and EMBASE, respectively. After removing duplicates, 4583 articles were left; their titles and abstracts were scanned, and 312 relevant articles were identified. The full texts of these 312 articles were further reviewed, after which 179 articles were included for data extraction (53 original articles and 126 other article types). The key information of the 53 original articles is summarized in Table 1, with the articles presented in alphabetical order by name of first author.

Table 1
Key information of the included original articles

No	First author	Title	Journal	Publication date	Specialty
1	Abdul Hafiz Oladapo Adesunkanmi	Impact of the COVID-19 Pandemic on Surgical Residency Training: Perspective from a Low-Middle Income Country	World Journal of Surgery	202010	Surgery
2	Adel Salah Alahmadi	Residents' Perceived Impact of COVID-19 on Saudi Ophthalmology Training Programs- A Survey	Clinical Ophthalmology	202011	Ophthalmology
3	Ahmad K Alhaj	Neurosurgery Residents' Perspective on COVID-19: Knowledge, Readiness, and Impact of this Pandemic	World Neurosurgery	202005	Neurosurgery
4	Ahmed M Gabr	Diagnostic and Interventional Radiology Case Volume and Education in the Age of Pandemics: Impact Analysis and Potential Future Directions	Academic Radiology	202006	Diagnostic and interventional radiology
5	Ameera Balhareth	Impact of COVID-19 pandemic on residency and fellowship training programs in Saudi Arabia: A nationwide cross-sectional study	Annals of Medicine and Surgery	202007	Multiple specialties
6	Anne L Cravero	Impact of exposure to patients with COVID-19 on residents and fellows: an international survey of 1420 trainees	Postgraduate Medical Journal	202009	Multiple specialties
7	Basil M Kahwash	Allergy/Immunology Trainee Experiences During the COVID-19 Pandemic: AAAAI Work Group Report of the Fellows-in-Training Committee	The Journal of Allergy and Clinical Immunology	202009	Allergy and Immunology

No	First author	Title	Journal	Publication date	Specialty
8	Cesare Zoia	COVID-19 and neurosurgical training and education: an Italian perspective	Acta Neurochirurgica	202006	Neurosurgery
9	Christoph Roemmele	Impact of the COVID-19 outbreak on endoscopy training in a tertiary care centre in Germany	Frontline Gastroenterology	202005	Endoscopy
10	Davide Pertile	The impact of COVID-19 pandemic on surgical residency programmes in Italy: a nationwide analysis on behalf of the Italian Polyspecialistic Young Surgeons Society (SPIGC)	Updates in Surgery	202006	Surgery
11	Deepak Mishra	The impact of COVID-19 related lockdown on ophthalmology training programs in India - Outcomes of a survey	Indian Journal of Ophthalmology	202005	Ophthalmology
12	Devang Odedra	Impact of COVID-19 on Canadian Radiology Residency Training Programs	Canadian Association of Radiologists Journal	202006	Diagnostic and interventional radiology
13	Dong-Gune Chang	The impact of COVID-19 pandemic on orthopaedic resident education: a nationwide survey study in South Korea	International Orthopaedics	202007	Orthopedics
14	E Christopher Ellison	Impact of the COVID-19 Pandemic on Surgical Training and Learner Well-Being: Report of a Survey of General Surgery and Other Surgical Specialty Educators	Journal of the American College of Surgeons	202008	Surgery

No	First author	Title	Journal	Publication date	Specialty
15	Edward J Caruana	Impact of coronavirus 2019 (COVID-19) on training and well-being in subspecialty surgery: A national survey of cardiothoracic trainees in the United Kingdom	The Journal of Thoracic and Cardiovascular Surgery	202005	Cardiothoracic surgery
16	Erin M White	Surgical Education in the Time of COVID: Understanding the Early Response of Surgical Training Programs to the Novel Coronavirus Pandemic	Journal of Surgical Education	202007	General surgery
17	Francesco Bandi	Strategies to overcome limitations in Otolaryngology residency training during the COVID-19 pandemic	European Archives of Oto-Rhino-Laryngology	202007	Otorhinolaryngology
18	Garrett N Cohan	The impact of COVID-19 on thoracic surgery residency programs in the US: A program director survey	Journal of Cardiac Surgery	202008	Thoracic surgery
19	Gaurav Kumar Upadhyaya	Impact of COVID-19 on post-graduate orthopaedic training in Delhi-NCR	Journal of Clinical Orthopaedics and Trauma	202007	Orthopedics
20	Geoffrey H Rosen	Effect of COVID-19 on Urology Residency Training: A Nationwide Survey of Program Directors by the Society of Academic Urologists	The Journal of Urology	202005	Urology
21	Giovanna Bitonti	Being an obstetrics and gynaecology resident during the COVID-19: Impact of the pandemic on the residency training program	The European Journal of Obstetrics & Gynecology and Reproductive Biology	202007	Gynecology

No	First author	Title	Journal	Publication date	Specialty
22	Hassan Aziz	Effect of COVID-19 on Surgical Training Across the United States: A National Survey of General Surgery Residents	Journal of Surgical Education	202007	General surgery
23	Hsiang-Yun Lo	What is the impact of the COVID-19 pandemic on emergency medicine residency training: an observational study	BMC Medical Education	202009	Emergency medicine
24	Jared Johnson	The impact of the COVID-19 pandemic on fellowship training: A national survey of pediatric otolaryngology fellowship directors	International Journal of Pediatric Otorhinolaryngology	202006	Pediatric Otorhinolaryngology
25	Jessica B Robbins	COVID-19 Impact on Well-Being and Education in Radiology Residencies: A Survey of the Association of Program Directors in Radiology	Academic Radiology	202006	Diagnostic and interventional radiology
26	Jian Zheng	General surgery chief residents' perspective on surgical education during the coronavirus disease 2019 (COVID-19) pandemic	Surgery	202006	General surgery
27	Johnathan A Khusid	Well-being and education of urology residents during the COVID-19 pandemic: Results of an American National Survey	International Journal of Clinical Practice	202005	Urology
28	Joshua D Burks	Early Changes to Neurosurgery Resident Training During the COVID-19 Pandemic at a Large U.S. Academic Medical Center	World Neurosurgery	202009	Neurosurgery

No	First author	Title	Journal	Publication date	Specialty
29	Julia R Coleman	COVID-19 Pandemic and the Lived Experience of Surgical Residents, Fellows, and Early-Career Surgeons in the American College of Surgeons	Journal of the American College of Surgeons	202009	Surgery
30	Katarzyna M Pawlak	Impact of COVID-19 on endoscopy trainees: an international survey	Gastrointestinal Endoscopy	202006	Gastrointestinal Endoscopy
31	Katherine E Fero	Perceived Impact of Urologic Surgery Training Program Modifications due to COVID-19 in the United States	Urology	202005	Urology
32	Khurram Shahzad Khan	Impact of the COVID-19 pandemic on core surgical training	Scottish Medical Journal	202008	Surgery
33	Kofi Clarke	Impact of COVID-19 Pandemic on Training: Global Perceptions of Gastroenterology and Hepatology Fellows in the USA	Digestive Diseases and Sciences	202010	Gastroenterology
34	Madhusudan Ganigara	Didactic education in paediatric cardiology during the COVID-19 pandemic: a national fellow survey	Cardiology in the Young	202010	Pediatric cardiology
35	Mariantonia Ferrara	Reshaping ophthalmology training after COVID-19 pandemic	Eye	202006	Ophthalmology
36	Medalit E Huamanchumo-Suyon	Impact of the COVID-19 pandemic on general surgery residency program in Peru: A cross-sectional study	Annals of Medicine and Surgery	202010	General surgery
37	Melissa K Meghpara	Repurposing a Small Community Hospital Surgical Residency Program in an Epicenter of the COVID-19 Pandemic	The American Journal of Surgery	202011	Surgery

No	First author	Title	Journal	Publication date	Specialty
38	Muhammad Osama	Impact of COVID-19 on surgical residency programs in Pakistan; A residents' perspective. Do programs need formal restructuring to adjust with the "new normal"? A cross-sectional survey study	International Journal of Surgery	202006	Surgery
39	Nahuel Paesano	Impact of COVID-19 Pandemic on Ibero-American Urology Residents: Perspective of American Confederation of Urology (CAU)	International Brazilian Journal of Urology	202007	Urology
40	Natalie A Homer	Oculoplastic fellow education during the COVID-19 crisis	Orbit	202010	Oculoplasty
41	Neo Poyiadji	COVID-19 and Radiology Resident Imaging Volumes– Differential Impact by Resident Training Year and Imaging Modality	Academic Radiology	202009	Diagnostic radiology
42	Paloma Del C Monroig-Bosque	Pathology Trainee Redeployment and Education During the COVID-19 Pandemic: An Institutional Experience	Academic Pathology	202007	Pathology
43	Panayiotis D Megaloikonomos	Impact of the COVID-19 pandemic on orthopaedic and trauma surgery training in Europe	International Orthopaedics	202007	Orthopedics
44	Panayiotis E Pelargos	An Evaluation of Neurosurgical Resident Education and Sentiment During the Coronavirus Disease 2019 Pandemic: A North American Survey	World Neurosurgery	202008	Neurosurgery

No	First author	Title	Journal	Publication date	Specialty
45	Raphael E Huntley	Early Effects of COVID-19 on Oral and Maxillofacial Surgery Residency Training-Results From a National Survey	Journal of Oral and Maxillofacial Surgery	202008	Oral and Maxillofacial Surgery
46	Robert J Rothrock	By the Numbers Analysis of Effect of COVID-19 on a Neurosurgical Residency at the Epicenter	World Neurosurgery	202007	Neurosurgery
47	S Veerasuri	Impact of COVID-19 on UK radiology training: a questionnaire study	Clinical Radiology	202007	Diagnostic and interventional radiology
48	Samit Shah	Impact of the COVID-19 pandemic on interventional cardiology training in the United States	Catheterization and Cardiovascular Interventions	202008	Interventional cardiology
49	Tanush Gupta	Impact of the COVID-19 pandemic on interventional cardiology fellowship training in the New York metropolitan area: A perspective from the United States epicenter	Catheterization and Cardiovascular Interventions	202005	Interventional cardiology
50	Theresa Guo	Impact of the COVID-19 pandemic on Otolaryngology trainee education	Head & Neck	202006	Otolaryngology
51	Tonya W An	How Are Orthopaedic Surgery Residencies Responding to the COVID-19 Pandemic? An Assessment of Resident Experiences in Cities of Major Virus Outbreak	Journal of the American Academy of Orthopaedic Surgeons	202008	Orthopedics
52	Virginia K Singla	The Impact of the COVID-19 Pandemic on Cardiac Electrophysiology Training: A Survey Study	Journal of Cardiovascular Electrophysiology	202011	Cardiovascular Electrophysiology

No	First author	Title	Journal	Publication date	Specialty
53	Zaid S Aljuboori	Early Effects of COVID-19 Pandemic on Neurosurgical Training in the United States: A Case Volume Analysis of 8 Programs	World Neurosurgery	202010	Neurosurgery

Quantitative analyses of original articles

Of the 53 original articles, 8, 11, 12, 7, 6, and 3 articles were published in May, June, July, August, September and October, and November 2020, respectively (Fig. 2). The geographic distribution of the research target group of the articles is presented in Fig. 3. By country, the most studies were performed in the United States (25 articles), followed by Italy and the United Kingdom (4 articles). Most studies focused on residency training in a single country, and only nine articles involved residents of multiple countries as the target group.

Subgroup analyses of original articles

Most of these original articles were questionnaire-based studies (n = 44, 83%). Among questionnaire-based studies, 35 (79.6%) involved residents directly, 6 (13.6%) involved program directors, and 3 (6.8%) involved both groups (Table 2). The distribution of published articles according to the degree of the COVID-19 pandemic is summarized in Table 3: 37 (84.0%), 2 (4.6%), and 3 (6.8%) articles were published in countries with > 1 000 000, 500 001–1 000 000, and 50 001–100 000 cases, respectively. Table 4 presents studies according to specialty. Most articles focused on surgery (n = 36, 67.92%) and interventional skill training in different specialties (n = 9, 16.98%).

Table 2
Study type and target group of included studies

Study design	article number (n)	%
Non-questionnaire	9	16.98
Questionnaire	44	83.02
Target research group		
Residents	35	79.55
Program directors	6	13.64
Both	3	6.82

Table 3
Distribution of included original articles by degree (case count) of COVID-19 pandemic

Cases-count of country	article number (n)	%
> 1000000	37	84.09
500001–1000000	2	4.55
50001–100000	3	6.82
5001–10000	1	2.27
1-50000	1	2.27

Table 4
Distribution of included original articles by specialty

Study field	article number (n)	%
Surgical	36	67.92
Medical	6	11.32
Interventional	9	16.98
Multiple	2	3.77

Possible effects of the COVID-19 pandemic on residency training

We summarize the effect of the COVID-19 pandemic of residency training mentioned in these articles in Table 5. The most common effect of the pandemic on residency training was decreased clinical experience and failure to meet the training requirements of the specialty. Furthermore, some articles mentioned redeployment to other tasks to manage the COVID-19 pandemic and some COVID-19-related problems, such as inadequate personal protective equipment (PPE) and quarantine policies. Moreover, residents had worse mental health and increased anxiety regarding their board exams and career. Educational activities such as lectures or case discussions may have increased or decreased depending on the situation. Furthermore, change in the working hours of residents varied based on hospital and specialty. Some articles reported decreased working hours because of reduced patient volume and elective operations. However, some residents may have experienced increased burdens because of extra work due to the pandemic.

Table 5
Summary of the effect of the COVID-19 pandemic on residency training

Decreased clinical experience and reduced case volume
Decreased quality of life and worse mental health
Redeployment to manage the COVID-19 pandemic
Failure to meet training requirements
Anxiety regarding board exams and career
COVID-19-related problems: inadequate personal protective equipment; quarantine policies
Educational activity: may increase or decrease (lectures and case discussions)
Working hours and burnout: may increase or decrease

Discussion

Our study is the first to systematically review and analyze published academic articles focusing on the effect of the COVID-19 pandemic on residency training after 1 year of the pandemic. We provided statistical information on the publication timeline, geographic distribution, publication types, and study specialties. In addition, we summarized the effect of the COVID-19 pandemic on residency training narratively.

The World Health Organization declared COVID-19 a pandemic on March 11, 2020. With respect to the global accumulation of cases, the number of confirmed patients with COVID-19 exceeded 1 million on April 2, and the number of deaths due to COVID-19 exceeded 100 000 on April 10 (9). The first original article on residency training during the pandemic was published on May 16, and publication on this topic peaked in July with 12 articles (10). This timeline reflects rapid intensification of the global pandemic in this period, which affected residency training in many specialties. Additionally, several developed countries, such as the United States, Italy, and the United Kingdom, had a rapidly increasing number of COVID-19 cases at this time, which may have been the reason for the increasing number of studies on this topic in these countries, given their focus on research and medical education.

Regarding geographic distribution, the studies were globally distributed, having been conducted in both developed or developing countries, and several multinational studies were also noted. Although the United States was responsible for almost half the articles reviewed, the results suggested that residency training programs were being affected globally by the COVID-19 pandemic. The effect of the pandemic on residency training should be identified by residency training program directors, and rolling adjustments and training program revisions are necessary to provide adequate training and maintain consistent quality during the pandemic.

The majority of the studies were published in countries severely affected by the pandemic, and therefore, medical education and residency training were substantially affected in these countries. Fewer elective operations because of policies established during the pandemic were noted in some specialties, such as urology, orthopedics, plastic surgery, and diagnostic angiography (11–14). The policies of lockdown and quarantine reduced patient volume for some diseases, such as trauma and infectious diseases, which induced less clinical exposure (15, 16). Redeployment and reassignment of residents occurred for pandemic-related work (17). All these factors contributed to possible inadequate training and failure to meet the requirements of training programs.

Surgical specialties were the most and first affected. Elective surgeries were cancelled or postponed during the pandemic, providing less practice and experience for the residents (11, 13, 14, 16). Additionally, residents in surgical specialties were redeployed to manage patients with COVID-19 or perform other work due to medical resource reallocation, disrupting their original surgical training courses. Another disruption was the “stay at home” policy, which resulted in fewer trauma cases and related surgeries (18). All these factors affected surgical resident training. A similar situation occurred in interventional medical fields, such as radiology, cardiology, and gastroenterology (12, 19, 20). Hands-on practice and on-the-job skill development in residency training were affected during the pandemic.

Although the effect of COVID-19 on the internal medicine field was rarely mentioned in the articles, the influence still existed. Residents focused on treating patients with COVID-19, which decreased their clinical experience with other diseases (21). The fear of becoming infected with COVID-19 in hospitals reduced patient volume, except for patients with possible or confirmed COVID-19 (22). Moreover, the policy of wearing a mask decreased the incidence of infectious diseases such as influenza (23). These conditions occurred in many countries, even in those less severely affected by the pandemic. Lo et al. published an observational study on the effect of the COVID-19 pandemic on emergency medicine residency training in a teaching hospital in Taiwan (24). As of this writing, in Taiwan, the number of patients with confirmed COVID-19 has remained under 1000, no large-scale lockdown has been implemented, and the health care system is robust. However, significant decreases were nevertheless noted in case volume and residents’ clinical exposure in Taiwan. Yet, the real effect of decreased clinical exposure is unknown because no study has assessed the learning outcomes of residents undergoing training during the pandemic.

The mental health and quality of life of residents have potentially been affected. The psychological pressure has been heavy when managing patients with COVID-19 because of infection risk and inadequate PPE in some hospitals. Quarantining due to caring for patients with confirmed COVID-19 and the fear of infecting family led residents to live alone with little family support (25). Excessive working hours and burnout have been common, although these factors have varied by individual. These factors can induce a stressed and unhealthy mental state and impair learning (26).

According to our results, most of the original studies used questionnaire surveys. In the early stage of the pandemic, the advantage of this research type was that it was quick, saved time, and was easily accessible (27). The results of these questionnaire surveys with either residents or program directors as respondents exhibited high consistency and reflected the effect of the COVID-19 pandemic on residents. However, these questionnaire studies had some limitations, such as subjective questions, voluntary response bias, and heterogeneity of respondents and institutional bias, which may limit their generalizability (28). Only nine studies had conducted objective investigations and had “real numbers” comparing the prepandemic and pandemic periods. These studies indicated the severity of the effect and identified domains that were affected. Further research of this type is warranted to comprehensively understand the influence of the pandemic.

Because insufficient training was a concern, some assisted teaching methods were suggested and attempted by medical educators and clinical teachers. These assisted methods included simulations, online courses, the flipped classroom approach, and virtual reality/augmented reality (29–31). Although these methods were adopted by many training program directors to compensate for the decreased clinical exposure and practice, the effect of doing so remained unknown because comparing learning outcomes between residency training in prepandemic and pandemic periods was impossible at this time. Extending training courses and delaying specialty board exams were considered options, but doing so could affect career planning and the quality of life of residents. The articles related to assisted teaching methods and adjustments were not included in our analysis because most of them were review articles rather than original works and failed to provide data regarding the effect. Although assisted teaching methods and

adjusting training courses appear necessary, research must be conducted to determine the effectiveness of these methods.

Limitations

This study has some limitations. First, we only selected articles published in English, and some important information published in different languages may have been overlooked. Second, articles included in our study were mainly published in American and European countries. Lack of data from other regions, even those severely affected by the pandemic, could render the conclusion insufficiently comprehensive. Third, the articles included in our study were within 1 year of the COVID-19 pandemic, and some long-term effects of this pandemic may not be evident in this time period. Finally, no article compared the learning outcomes of residents between prepandemic and pandemic periods. The final performance of these residents remains unknown. Further studies are necessary to determine the learning outcomes of residency training during this pandemic.

Conclusions

The COVID-19 pandemic has greatly affected residency training globally, particularly surgical and interventional medical fields. Decreased clinical experience, reduced case volume, and disrupted education activities are major concerns in all fields. Although the publication of original studies investigating the effect of the COVID-19 pandemic on residency training is increasing, as of this writing, no study has compared the learning outcomes of residents between prepandemic and pandemic periods. Further study should be focused on the learning outcomes of residency training during the epidemic and evaluate the effectiveness of assisted teaching methods.

Declarations

Data Availability Statement: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical approval: The Chang Gung Medical Foundation Institutional Review Board approved this study (IRB: 202100338B1).

Prior Presentations: This research has not been presented previously.

Conflict of interest: There are no conflicts of interest to declare.

Funding sources/Disclosures: There is no funding to disclose.

Author Contribution: Conceptualization: Chen and Lo; Data curation: Lo and Hung; Formal analysis: Chen and Hung; Figure preparation: Hung; Investigation: Chen, Lo and Hung; Writing-original draft: Lo and Hung; Writing-review&editing: Chen

Acknowledgments: This research was supported by Chang-Gung Memorial Hospital. We are thankful to our colleagues who provided their expertise, which greatly assisted the research, although they may not agree with all the interpretations provided in this paper.

References

1. Blumenthal D, Fowler EJ, Abrams M, Collins SR. Covid-19 - Implications for the Health Care System. *N Engl J Med*. 2020;383(15):1483–8.
2. Di Gennaro F, Pizzol D, Marotta C, Antunes M, Racalbuto V, Veronese N, et al. Coronavirus Diseases (COVID-19) Current Status and Future Perspectives: A Narrative Review. *Int J Environ Res Public Health*. 2020;17(8).
3. Carpenter CR, Mudd PA, West CP, Wilber E, Wilber ST. Diagnosing COVID-19 in the Emergency Department: A Scoping Review of Clinical Examinations, Laboratory Tests, Imaging Accuracy, and Biases. *Acad Emerg Med*. 2020;27(8):653–70.
4. Greenland JR, Michelow MD, Wang L, London MJ. COVID-19 Infection: Implications for Perioperative and Critical Care Physicians. *Anesthesiology*. 2020;132(6):1346–61.
5. Farooq RK, Rehman SU, Ashiq M, Siddique N, Ahmad S. Bibliometric analysis of coronavirus disease (COVID-19) literature published in Web of Science 2019–2020. *J Family Community Med*. 2021;28(1):1–7.
6. Dedeilia A, Sotiropoulos MG, Hanrahan JG, Janga D, Dedeilias P, Sideris M. Medical and Surgical Education Challenges and Innovations in the COVID-19 Era: A Systematic Review. *In Vivo*. 2020;34(3 Suppl):1603–11.
7. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med*. 2018;169(7):467–73.
8. WHO Coronavirus (COVID-19) Dashboard [cited 2021 20, March]. Available from: <https://covid19.who.int/>.
9. WHO Rolling updates on coronavirus disease (COVID-19) 31, July. 2020 [cited 2021 20, March]. Available from: <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen>.
10. Gupta T, Nazif TM, Vahl TP, Ahmad H, Bortnick AE, Feit F, et al. Impact of the COVID-19 pandemic on interventional cardiology fellowship training in the New York metropolitan area: A perspective from the United States epicenter. *Catheter Cardiovasc Interv*. 2021;97(2):201–5.
11. Bregman DE, Cook T, Thorne C. Estimated National and Regional Impact of COVID-19 on Elective Case Volume in Aesthetic Plastic Surgery. *Aesthet Surg J*. 2021;41(3):358–69.
12. Gabr AM, Li N, Schenning RC, Elbarbary A, Anderson JC, Kaufman JA, et al. Diagnostic and Interventional Radiology Case Volume and Education in the Age of Pandemics: Impact Analysis and Potential Future Directions. *Acad Radiol*. 2020;27(10):1481–8.
13. Lewicki P, Basourakos SP, Al Awamlh BAH, Wu X, Hu JC, Schlegel PN, et al. Estimating the Impact of COVID-19 on Urology: Data from a Large Nationwide Cohort. *Eur Urol Open Sci*. 2021;25:52–6.
14. Swiatek PR, Weiner J, Alvandi BA, Johnson D, Butler B, Tjong V, et al. Evaluating the Early Impact of the COVID-19 Pandemic on Sports Surgery Fellowship Education. *Cureus*. 2021;13(1):e12943.
15. Angoulvant F, Ouldali N, Yang DD, Filser M, Gajdos V, Rybak A, et al. COVID-19 pandemic: Impact caused by school closure and national lockdown on pediatric visits and admissions for viral and non-viral infections, a time series analysis. *Clin Infect Dis*. 2020.
16. Donovan RL, Tilston T, Frostick R, Chessier T. Outcomes of Orthopaedic Trauma Services at a UK Major Trauma Centre During a National Lockdown and Pandemic: The Need for Continuing the Provision of Services. *Cureus*. 2020;12(10):e11056.
17. Clarke K, Bilal M, Sánchez-Luna SA, Dalessio S, Maranki JL, Siddique SM. Impact of COVID-19 Pandemic on Training: Global Perceptions of Gastroenterology and Hepatology Fellows in the USA. *Dig Dis Sci*. 2020:1–5.
18. Kamine TH, Rembisz A, Barron RJ, Baldwin C, Kromer M. Decrease in Trauma Admissions with COVID-19 Pandemic. *West J Emerg Med*. 2020;21(4):819–22.
19. Banerjee S, Tarantini G, Abu-Fadel M, Banerjee A, Little BB, Sorajja P, et al. Coronavirus Disease 2019 Catheterization Laboratory Survey. *J Am Heart Assoc*. 2020;9(15):e017175.

20. Chai N, Tang X, Linghu E, Feng J, Ye L, Wu Q, et al. The influence of the COVID-19 epidemic on the gastrointestinal endoscopy practice in China: a national survey. *Surg Endosc*. 2020;1–8.
21. Kahwash BM, Deshpande DR, Guo C, Panganiban CM, Wangberg H, Craig TJ. Allergy/Immunology Trainee Experiences During the COVID-19 Pandemic: AAAAI Work Group Report of the Fellows-in-Training Committee. *J Allergy Clin Immunol Pract*. 2021;9(1):1–6.e1.
22. Jeffery MM, D'Onofrio G, Paek H, Platts-Mills TF, Soares WE, 3rd, Hoppe JA, et al. Trends in Emergency Department Visits and Hospital Admissions in Health Care Systems in 5 States in the First Months of the COVID-19 Pandemic in the US. *JAMA Intern Med*. 2020;180(10):1328–33.
23. Soo RJJ, Chiew CJ, Ma S, Pung R, Lee V. Decreased Influenza Incidence under COVID-19 Control Measures, Singapore. *Emerg Infect Dis*. 2020;26(8):1933–5.
24. Lo HY, Lin SC, Chaou CH, Chang YC, Ng CJ, Chen SY. What is the impact of the COVID-19 pandemic on emergency medicine residency training: an observational study. *BMC Med Educ*. 2020;20(1):348.
25. Cravero AL, Kim NJ, Feld LD, Berry K, Rabiee A, Bazarbashi N, et al. Impact of exposure to patients with COVID-19 on residents and fellows: an international survey of 1420 trainees. *Postgrad Med J*. 2020.
26. Aziz H, James T, Remulla D, Sher L, Genyk Y, Sullivan ME, et al. Effect of COVID-19 on Surgical Training Across the United States: A National Survey of General Surgery Residents. *J Surg Educ*. 2021;78(2):431–9.
27. Safdar N, Abbo LM, Knobloch MJ, Seo SK. Research Methods in Healthcare Epidemiology: Survey and Qualitative Research. *Infect Control Hosp Epidemiol*. 2016;37(11):1272–7.
28. Michael Coughlan PC, Frances Ryan. Survey research: Process and limitations. *International Journal of Therapy and Rehabilitation*. 2009;16.
29. Ellison EC, Spanknebel K, Stain SC, Shabahang MM, Matthews JB, Debas HT, et al. Impact of the COVID-19 Pandemic on Surgical Training and Learner Well-Being: Report of a Survey of General Surgery and Other Surgical Specialty Educators. *J Am Coll Surg*. 2020;231(6):613–26.
30. Shah S, Diwan S, Kohan L, Rosenblum D, Gharibo C, Soin A, et al. The Technological Impact of COVID-19 on the Future of Education and Health Care Delivery. *Pain Physician*. 2020;23(4s):S367-s80.
31. Wilcha RJ. Effectiveness of Virtual Medical Teaching During the COVID-19 Crisis: Systematic Review. *JMIR Med Educ*. 2020;6(2):e20963.

Figures

Figure 1

PRISMA flow diagram of the study selection process

Figure 2

Time distribution of the published articles

Figure 3

Geographic distribution of the published articles