



Review

The impact of the COVID-19 pandemic on surgical education: A survey and narrative review



Narjes Mohammadzadeh^a, Kiana Tadbir Vajargah^b, Neda Nilforoushan^a,
 Mohammad Ashouri^{a,*}, Ali Jafarian^{a,c}, Seyed Hassan Emami-Razavi^a

^a Department of Surgery, Tehran University of Medical Sciences, Tehran, Iran

^b School of Medicine, Tehran University of Medical Sciences, Tehran, Iran

^c Liver Transplantation Research Centre, Tehran University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Keywords:

COVID 19
 Pandemic
 Surgical education
 Surgical residency
 Surgical training

ABSTRACT

Background: Since the emergence of the COVID-19 pandemic, medical education has been a concerning issue, especially in surgical fields. Due to the postponement of many elective surgeries and even alternations in the pattern of emergent surgeries, concerns have been raised about whether residents of surgical disciplines are experienced enough after graduation or not. We aimed to describe the impact of the COVID-19 pandemic on surgical residency training in different fields.

Materials and methods: We conducted a cross-sectional study with a 20-item questionnaire on residents of surgical disciplines from three different educational hospitals of Tehran University of Medical Sciences, Iran in 2020. In addition, we reviewed the current literature regarding the impact of COVID-19 pandemic on surgical education worldwide.

Results: Our survey, with a response rate of 56.8% demonstrated significant reduction in the time spent in elective surgeries, surgical clinics and even in emergent surgeries for residents. Besides, it has reported that significant time has been spent in COVID 19 wards which resulted in decreased satisfaction of educational activities.

Conclusions: The impacts of COVID 19 pandemic on surgical education are significant and inevitable. Thus, we must integrate novel educational methods in surgical curriculum to optimize training and minimize the adverse effects of the pandemic on surgical education.

Introduction

The coronavirus disease (COVID-19), first recognized in Wuhan, China has spread throughout the world at an unprecedented rate [1]. COVID-19 has been a serious health concern in the world and Iran, with this nation having the 11th highest national death toll in the world [2]. Due to the unparalleled number of patients resultant from the pandemic, the healthcare system in Iran, as well as many others, was overcrowded by the shortage of adequate resources [3]. Thus, guidelines were put in place to prioritize the care for COVID-19 patients and most non-urgent outpatient visits and elective surgeries were postponed [4]. Likewise, a dramatic reduction in educational opportunities and hands-on experience in surgical specialties resulted and raised the question of whether the surgical residents would have gained adequate experience for

high-quality patient care upon the completion of residency program [5, 6].

A better understanding of the impacts of the COVID-19 pandemic on surgical education is essential for improvements in educational curricula. We aimed to evaluate the impact of COVID-19 on surgical disciplines in educational hospitals associated to Tehran University of Medical Sciences (TUMS). Therefore, a questionnaire with a focus on surgical education was designed and it was filled out by residents of different surgical disciplines. Moreover, we reviewed the previously published experiences of other countries and we made suggestions on how to turn this challenge into opportunity.

* Corresponding author. Imam Khomeini Hospital Complex, Dr Gharib St, Keshavarz Blvd, Tehran, 1419733141, Iran.

E-mail addresses: nmohammadzadeh@sina.tums.ac.ir (N. Mohammadzadeh), tadbir.kiana@gmail.com (K. Tadbir Vajargah), neda.nilforoushan@gmail.com (N. Nilforoushan), m-ashouri@tums.ac.ir (M. Ashouri), jafarian@tums.ac.ir (A. Jafarian), emamiraz@sina.tums.ac.ir (S.H. Emami-Razavi).

<https://doi.org/10.1016/j.amsu.2022.104598>

Received 23 July 2022; Received in revised form 29 August 2022; Accepted 4 September 2022

Available online 9 September 2022

2049-0801/© 2022 The Authors. Published by Elsevier Ltd on behalf of IJS Publishing Group Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Methods

This was a cross-sectional and survey-based study held in Imam Khomeini Hospital Complex (IKHC), Sina Hospital and Shariati Hospital, TUMS with the aim of investigating the effects of the COVID-19 pandemic on the quality of surgical education. Thus, the study population was surgical residents of different disciplines, including general surgery, orthopedics, urology, obstetrics and gynecology (OB/GYN), and neurosurgery in all three hospitals. Ethical approval was obtained from the ethics committee of TUMS. To formulate a valid and accurate questionnaire, possible factors associated with the quality of residents' education were determined based on several focus group discussions (FGD). Successively, an online questionnaire based on Google Forms was created using the FGD findings. This questionnaire was divided into three sections including questions about the demographics of the resident, reported degree of satisfaction with the current training system, and the mean working and resting hours during the COVID-19 pandemic.

In order to review the current literature on the impact of COVID-19 on surgical education, we searched the PubMed (National Center for Biotechnology Information) database and used the Google Scholar to shape our narrative review. The search was conducted on English-language articles available in peer-reviewed journals. There were no limitations regarding publication time. We focused on residents of different surgical disciplines as our population of interest. As a result, we conducted title and abstract searches using the following keywords for participants: residents, trainees, fellows, COVID-19, coronavirus, and pandemic. Eligible articles were ones in which participants were residents or fellows and reported the impacts of the COVID-19 pandemic on the defined subjects. Studies were excluded when the term "residents" referred to disciplines other than medicine.

The degree of the normality of the distribution of quantitative data was deliberated using the Kolmogorov-Smirnov test and the Q-Q graphical method. Additionally, quantitative variables were described as mean (standard deviation) or median (first quarter-third quarter) as best suited based on these tests, and qualitative variables were described as the percentage of respondents. To compare quantitative variables between groups, *t*-test (Mann-Whitney test) and analysis of variance (Kruskal-Wallis's test) were used. Paired *t*-test was used to compare quantitative variables before and after the pandemic. All statistical analyses were performed using SPSS software version 24. The level of statistical significance was less than 0.05, and the marginal statistical significance was between 0.05 and 0.1.

Results

The questionnaire was sent to all residents of different surgical specialties. A total of 104 out of 183 residents (general surgery (62/69), orthopedics (9/36), urology (7/15), OB/GYN (20/38), and neurosurgery (6/25)) completed the questionnaire (Response rate, 56.8%).

1. How has COVID-19 pandemic affected surgical residents' schedules?
 a. Visit of COVID-19 Patients; An Extra Duty

Due to the limited resources during a pandemic, surgical trainees were reallocated to participate in the management of COVID-19 patients or attend COVID-19 wards, which interrupted their surgical training [8-10]. A survey on surgical residency programs in Italy demonstrated that 14.8% of participants have been reallocated to a nonsurgical unit or have voluntarily interrupted their training to attend a COVID-19 unit [7]. According to another study conducted at the US surge of the pandemic, 14% of otolaryngology residents were transferred to other departments, mostly ICUs or COVID-19 wards. These trainees were significantly more concerned in terms of anxiety and burnout, and experienced lower levels of wellbeing. They also experienced higher levels of concern for getting ill and transmitting COVID-19, but this did

not reach statistical significance [8]. A global survey on the impact of the COVID-19 pandemic on surgical training revealed that COVID-19-associated emergency care, reallocation to other specialties or alterations in duties within the same specialties have led to disruption and fewer opportunities for surgical trainees [9].

According to our survey, the surgical trainees spent a median of 5.5 h weekly in the COVID-19 wards. Remarkably, this value was higher for female trainees when compared to their male counterparts (8 vs. 2 h in a week, respectively). However, the mean time spent at the COVID-19 wards did not significantly differ between the IKHC, as the main referral hospital for COVID-19 patients, and the other surveyed hospitals (P = 0.24).

b. Emergency Surgeries

A disruption in surgical training, in part due to social distancing, was observed in numerous previous studies due to the decreased trauma admissions and emergency department visits [10-21]. In our survey, 53.9% of residents experienced less than 50% decrease in emergency operating room attendance, while 29.8% of them reported a reduction of more than 50% in their attendance. Moreover, 64.5% of residents reported a less than 50% decrease in the number of surgeries in the emergency operating room, while 25% of them experienced a reduction of more than 50% in the number of emergency surgeries (Table 1).

c. Elective Services

Surgical fields were one of the first and most disrupted trainings due to canceled or deferred elective surgeries and decreased surgical services during the pandemic. Thus, surgical residents of various specialties have been adversely affected in terms of less hands-on opportunities and operative experience [22-26]. In our survey, 94.2% of residents expressed a decrease in the number of elective surgeries while 44.3% of them stated that their presence in the elective operating room had decreased more than 50% due to the pandemic. Overall, 74% of the residents reported that their time in the surgical clinic was also reduced (Table 1).

2. How has the COVID-19 pandemic affected didactics in surgical training?

A scoping review on the impact of COVID-19 on surgical training in the United States, United Kingdom, Canada, Australia, and New Zealand has demonstrated that during the pandemic, face-to-face courses and conferences have been deferred, and curricular trainings were provided through webinars, virtual platforms, and open access virtual resources [27]. A survey of general surgery residency programs in the United

Table 1
 The reported change (%) in the number of surgeries, time spent in emergency and elective operating rooms, and attendance at the surgical clinic.

Reported Decrease (%)	Time Spent in Emergency Operating Room ^a	Number of Emergency Surgeries ^a	Time Spent in Operating Room ^a	Number Elective Surgeries ^a	Time Spent in Surgical Clinic ^a
0-25	27 (26.0%)	35 (33.7%)	20 (19.2%)	22 (21.2%)	35 (33.7%)
25-50	29 (27.9%)	32 (30.8%)	30 (28.8%)	32 (30.8%)	24 (23.1%)
50-75	17 (16.3%)	22 (21.2%)	22 (21.2%)	20 (19.2%)	12 (11.5%)
75-100	14 (13.5%)	4 (3.8%)	24 (23.1%)	24 (23.1%)	6 (5.8%)
No Change	17 (16.3%)	11 (10.6%)	8 (7.7%)	6 (5.8%)	27 (26.0%)

^a Data are presented as number of participants (percentage %).

States have revealed similar results with decreased in-person education time, and increased virtual didactics [28]. In a study conducted in Italy, 29.5% of residents allocated to COVID-19 emergency units postponed surgical didactic activities, while 19.6% increased their activities [7]. Similarly, an online survey of general surgery residents across the United States has demonstrated that while didactics were moved towards virtual platforms, the majority of trainees spent more time on educational didactics than before the pandemic [29].

Another study on orthopedic and trauma surgery trainees in Europe has indicated that the teaching duties of residents, in terms of didactic education have decreased, and the traditional modalities of faculty-led and bedside education were limited as well. However, most participants stated that remote clinical learning increased and academic education in virtual research was similar or even higher [30]. In a qualitative study, surgical trainees perceived the pandemic as an unexpected opportunity and reported more reading time, increased time for self-study, and didactics. In addition, more online resources had helped to fill in the previous gap in education [31].

In line with the previous studies, our data demonstrate that during the pandemic, the resting time, time for self-study, and virtual education have increased 82.8%, 70.2%, and 76.9%, respectively. Furthermore, 82.7% of trainees reported that their face-to-face education time was reduced (Table 2). Based on our survey, 18.3%, 41.3%, and 40.4% of trainees reported improved, no changes, and a reduction in the quality of education during the pandemic, respectively.

3. How has the COVID-19 pandemic impacted surgical trainees' satisfaction?

A study on the perception of neurosurgery residents on online webinars during the COVID-19 pandemic revealed that 89% of residents were satisfied with online webinars, while 75% of them found online lectures more useful than traditional lectures [32]. Another study on the perception of E-learning during the pandemic demonstrated that trainees had higher satisfaction in comparison to in-person learning, with 51.4% of them supporting E-learning [33]. In a study of otolaryngology trainees at the US COVID-19 surge, 75% of trainees were satisfied with the departments' response to COVID-19 and 75% were comfortable expressing their concerns to the attending faculty. Their level of satisfaction was associated with the comfort in communicating their concerns [8].

According to our survey, 48.1% of residents have reported worsened satisfaction with clinical classes, while 12.5% reported no changes in satisfaction. Overall, the mean difference in the satisfaction score with the clinical classes after COVID-19 decreased by 1.65 (1.15–1.16) units, which was statistically significant ($P < 0.001$). The decrease in satisfaction with clinical classes was significantly greater in older ($P = 0.02$), female trainees ($P = 0.04$). Moreover, senior trainees experienced smaller drops in satisfaction when compared to junior trainees ($P = 0.02$) (Tables 3 and 4). The same trend was observed when non-general surgery residents were compared to general surgery trainees ($P = 0.05$), and junior residents were compared to the seniors ($P = 0.01$). Moreover, trainees who allocated more visiting hours for COVID-19 patients

Table 2
The reported change (%) in resting time, study time, face-to-face class time, and virtual class time.

Reported Change (%)	Increase in Resting Time ^a	Increase in Study Time ^a	Reduction in Face-to-Face Class Time ^a	Increase in Virtual Class Time ^a
0–25	43 (41.3%)	37 (35.6%)	36 (34.6%)	32 (30.8%)
25–50	33 (31.7%)	21 (20.2%)	16 (15.4%)	24 (25%)
50–75	6 (5.8%)	8 (7.7%)	16 (15.4%)	10 (9.6%)
75–100	4 (3.8%)	7 (6.7%)	18 (17.3%)	13 (12.5%)
No Change	18 (17.3%)	31 (29.8%)	18 (17.3%)	24 (23.1%)

^a Data are presented as number of participants (percentage %).

reported a higher rate of dissatisfaction.

4. What has confounded the impact of COVID-19 on surgical training?
a. Postgraduate Year (PGY):

Wise et al. investigated the impact of COVID-19 on surgical residents' education and coping. They demonstrated that 43.9% of junior residents perceived virtual learning better than traditional methods, in comparison to 36.8% of senior residents and fellows [31]. Rana et al. studied the residents' perspectives on the effect of COVID-19 on medical education. They observed remarkable differences between junior and senior residents. Seniors indicated that the pandemic was disruptive to their training, more than juniors, due to the loss of opportunities to execute responsibilities independently and lack of time to make up for the lost opportunities. Nevertheless, seniors were more satisfied with the altered programs in comparison to junior residents. Seniors were more comfortable with online education, although they found online meetings less effective compared to junior residents [34].

In a study conducted on general surgery clinical teaching units at three sites of the McGill University, the effects of the pandemic on operating room attendance and surgical case types differed across levels of training. Compared to senior residents, juniors were much more affected with 68% case attendance and 68% operating time in comparison to the pre-pandemic baseline. Senior trainees attended 73% of the baseline number of cases, with 77% of the baseline operating time [35].

Our survey demonstrated that senior trainees (PGY3-4) had increased resting time ($P = 0.003$). They also spent more time on self-study ($P = 0.05$) and virtual classes ($P = 0.03$) during the pandemic. Furthermore, senior residents reported a smaller reduction in satisfaction in comparison to junior residents ($P = 0.02$). However, there were no statistically significant differences in terms of face-to-face class time among different training levels. According to our survey, the visit time for COVID-19 patients was higher in junior (PGY1-2) residents when compared to the senior ones.

b. Training Hospitals:

Based on our survey, the difference in COVID-19 visit time was not statistically significant between residents of different hospitals. The increase in study time ($P = 0.02$) and virtual class time ($P = 0.05$) in IKHC residents was significantly higher in comparison to other hospitals, while the differences regarding resting time and face-to-face class time were not statistically significant. Unlike emergency services, the reduction in the time spent in the elective operating room and the number of elective surgeries was significantly higher in residents of IKHC when compared to other hospitals. In addition, the rate of attendance at the surgical clinic was higher for IKHC residents. It is noteworthy that among the studied hospitals, IKHC was the largest hospital, admitting more COVID-19 patients during the pandemic. Moreover, prior to and during the COVID-19 pandemic, IKHC had a higher volume of surgical cases in comparison to the other two hospitals.

c. Specialties:

In a study conducted on general surgery units of the McGill University, the effects of the pandemic on operating room attendance and surgical case types differed across various specialties. The minimally invasive surgery and colorectal fellows were the most (14% of baseline cases) and the least (75% of baseline cases) affected specialties, respectively. In all levels, the reduction in operation time was compatible with the reduction in case number, except for the colorectal trainees who experienced 75.4% of case numbers, with 89.0% of baseline operating time, probably due to the more complex cases. The pandemic's influence was largest on the minimally invasive surgery and bariatrics trainees, with 19% and 43% of baseline cases, respectively. Fewer

Table 3
The reported change in satisfaction levels with face-to-face classes.

Demographic Characteristics		All participants ^a	Change in Satisfaction with face-to-face Classes ^a			P Value
			Decreased (n = 42)	No Change (n = 43)	Increased (n = 19)	
Age (Year)		30.27 ± 2.87	31.54 ± 3.43	29.88 ± 2.33	30.84 ± 1.8	0.02
Gender (female-male)		42–62	21–21	18–25	3–16	0.04
Hospital	Imam Khomeini	39 (37.7%)	17 (40.5%)	14 (32.6%)	8 (42.1%)	0.66
	Sina	44 (42.3%)	19 (45.2%)	19 (44.2%)	6 (31.9%)	
	Shariati	21 (20.2%)	6 (14.3%)	10 (23.3%)	5 (26.3%)	
Residency Program	General Surgery	62 (59.6%)	22 (52.4%)	24 (55.8%)	16 (84.2%)	0.05
	OB/GYN	20 (19.2%)	11 (26.2%)	9 (20.9%)	0 (0.0%)	
	Orthopedics	9 (8.7%)	3 (7.1%)	4 (9.3%)	2 (10.5%)	
	Urology	7 (6.7%)	2 (4.8%)	4 (9.3%)	1 (5.3%)	
	Neurosurgery	6 (5.8%)	4 (9.5%)	2 (4.7%)	0 (0.0%)	
Residency Year	PGY1	26 (25%)	10 (23.8%)	13 (30.2%)	3 (15.8%)	0.01
	PGY2	28 (26.9%)	14 (33.3%)	10 (23.3%)	4 (21.1%)	
	PGY3	29 (27.9%)	14 (33.3%)	11 (25.6%)	4 (21.1%)	
	PGY4	21 (20.2%)	4 (9.5%)	9 (20.9%)	8 (42.1%)	

^a Data are presented as mean ± standard deviation, or number of participants (percentage %).

Table 4
The reported change in satisfaction levels with clinical classes.

Demographic Characteristics		All participants ^a	Change in Satisfaction with Clinical Classes ^a			P Value
			Decreased (n = 50)	No Change (n = 41)	Increased (n = 13)	
Age (Year)		30.27 ± 2.87	31	30	30	0.70
Gender (female-male)		42–62	26–24	7–34	9–4	0.001
Hospital	Imam Khomeini	39 (37.7%)	21 (42.0%)	13 (31.7%)	5 (38.5%)	0.60
	Sina	44 (42.3%)	19 (38.0%)	18 (43.9%)	7 (35.8%)	
	Shariati	21 (20.2%)	10 (20.0%)	10 (24.4%)	1 (7.7%)	
Residency Program	General Surgery	62 (59.6%)	27 (54.0%)	28 (68.3%)	7 (53.8%)	0.35
	OB/GYN	20 (19.2%)	13 (26.0%)	3 (7.3%)	4 (30.8%)	
	Orthopedics	9 (8.7%)	0 (0.0%)	7 (17.1%)	2 (15.4%)	
	Urology	7 (6.7%)	5 (10.0%)	2 (4.9%)	0 (0.0%)	
	Neurosurgery	6 (5.8%)	5 (10.0%)	1 (2.4%)	0 (0.0%)	
Residency Year	PGY1	26 (25%)	11 (22.0%)	15 (36.6%)	0 (0.0%)	0.43
	PGY2	28 (26.9%)	13 (26.0%)	10 (24.4%)	5 (38.5%)	
	PGY3	29 (27.9%)	16 (32.0%)	6 (16.4%)	7 (53.8%)	
	PGY4	21 (20.2%)	10 (20.0%)	10 (24.4%)	1 (7.7%)	

^a Data are presented as mean ± standard deviation, or number of participants (percentage%).

limitations were imposed on colorectal and hepatopancreatobiliary surgery trainees, with 91% and 82% of baseline cases, respectively [35].

According to our survey, general surgery residents reported higher increase in time for self-study and resting. The increase in virtual class time was lower for general surgery residents in comparison to other surgical specialties, while the face-to-face class time was not significantly different between residents of different surgical specialties. The reduction in the number of emergency and elective surgeries for specialties other than general surgery were higher than general surgery residents and the observed difference was marginally significant (P = 0.07 and P = 0.02 respectively).

Discussion

More than two years has passed since the worldwide emergence of COVID-19 and the effects of this catastrophic pandemic is explicit in all aspects of daily life [36,37]. Colleges around the world have been closed, and online instruction has unexpectedly become an academic standard. Under these circumstances, teachers and students might consider the rapid transition to online instruction disappointing and distracting. Based on previous experiences, specialists have anticipated that it might take 5–10 years to recover from this pandemic [38]. In addition to reviewing the current literature, we asked surgical residents of different surgical disciplines to report on the quality of training and satisfaction with medical education during this pandemic. Our results suggest that there are many adverse outcomes to consider when

evaluating the impact of COVID-19 crisis on medical education, specifically surgical fields.

Decrease in clinical activities (emergency and elective operations as well as pre-operative and post-operative care) and educational activities (theoretical training) was notable among surgical residents of different specialties, which was comparable to previous reports [37]. This should be used as a reminder for medical education systems to evaluate and alter the training curriculum as needed during pandemics. The learning opportunities for surgical residents have decreased due to the cessation of elective surgeries during the pandemic. Conclusively, surgical residents are tending to experience a more disrupted training in comparison to residents of non-surgical specialties. Rana et al. reported that medicine residents were more comfortable than surgical residents using tele-medicine [34].

The results of this investigation also highlighted that the level of satisfaction with both theoretical training and clinical training was reduced especially in residents with more exposure to COVID-19 patients. The COVID-19 pandemic has significantly affected postgraduate education, but educators have responded promptly to flatten the impact. This attempt ranged from decreased working hours while maintaining enough exposure to emergency operations. At the same time, there was a shift from the reduced operative and clinical tasks towards more educational and scientific programs [39–41].

This study shows that the surgical residency curriculum requires revisions as well as innovative approaches. The results indicate that improvement of educational programs in referral centers (such as IKHC)

is essential since such hospitals have limited resources and are affected more strongly due to the high number of COVID-19 patients. This shortage of resources in turn has a direct negative impact on the surgical training plans due to the limited number of patients receiving surgical treatment. Moreover, surgical residents of such referral hospitals have to participate in the COVID-19 wards and provide care for COVID-19 patient. This extra duty can deviate residents from their training programs. Although we investigated almost all surgical specialties, further research into the experiences of different surgical and non-surgical disciplines will shed light on the difference between subgroups and facilitate widely-applicable and successful changes to both guidelines and medical curriculum, thus, facilitating an improved quality of education for medical practitioners worldwide. This in turn would lead to an increased level of medical expertise and result in better patient outcomes.

To improve, we suggest that online training methods, including on-line and interactive multimedia resources, social media, virtual rounds, virtual conferencing, live surgery feeds, annotated videos of surgical procedures, and if available, virtual 3D software for physical examinations, anatomic dissections, and basic surgical skills can be implemented into the surgical curriculum. For example, videos of operations can be played for trainees during online classes while the faculty explains the procedure and answers any queries or confusions the residents may have faced. Moreover, operations performed by the attending faculty and a team of residents at the hospital can be live-streamed and successively discussed with other residents who could not attend the operation in person.

As another suggestion for improving education during the pandemic, surgical simulator devices, which were previously used for laparoscopic training, can be more extensively integrated into the training programs. This could allow for more hands-on experience and improvements in technical performance and skills for all surgical trainees. In other words, residents can perform the selected procedures and operations using simulator devices under the supervision of a senior resident or attending faculty and then independently. Finally, virtual reality and online simulator applications designed for the training of open and laparoscopic surgeries can play a beneficial role in the surgical training, especially at COVID-19 surges. Overall, the suggestions mentioned earlier must be tested and discussed with focus groups and investigated in terms of their success in improving the quality of education for surgical residents [42–52].

Limitations: This study was a narrative review and survey on the impact of COVID-19 pandemic on surgical education. This study has several limitations. First, the study is limited by its descriptive nature and the modest sample size. Second, the literature search was narrow and limited to English-language studies. Third, no assessment on quality of included studies was performed. Lastly, the low response rate in our study might introduce a sampling bias.

Conclusions

The COVID-19 pandemic has posed a substantial impact on the training of different surgical disciplines. Reduced clinical and surgical opportunities, decreased case volume, and disruption in face-to-face education are considered as main concerns in surgical training. Despite its disadvantages, increased time for resting, self-study, and satisfaction with virtual learning platforms to some extent, had made an opportunity out of the pandemic for surgical residents. We suggest that online training methods, virtual 3D platforms for physical examinations, anatomic dissections, and basic surgical skills, and surgical simulator devices can be more extensively integrated into the surgical curriculum. Moreover, operations performed by the attending faculty and a team of residents at the hospital can be live-streamed and successively discussed with other residents. However, the long-term impact of COVID-19 pandemic on surgical training has yet to be sought and the mentioned suggestions must be investigated in terms of success in improving the quality of surgical education.

Funding

This study has been supported by Tehran University of Medical Sciences & Health Services grant. The funder had no role in study design, data collection, analysis or writing the manuscript. The grant number is IR.TUMS.VCR.REC.1399.174.

Ethical approval

Ethical approval was obtained from the ethics committee of TUMS.

Author contribution

All authors have contributed to this study equally.

Conflicts of interest

There is no conflicts of interest to disclose.

Registration of research studies

1. Name of the registry: N/A
2. Unique Identifying number or registration ID: N/A
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): N/A

Guarantor

Mohammad Ashouri.

Consent

Written informed consent was obtained from the study participants.

Acknowledgements

Authors would like to appreciate the support and constructive comments of the methodologist(s) research development office, Imam Khomeini Hospital Complex, Tehran, Iran.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amsu.2022.104598>.

References

- [1] C. Sohrabi, Z. Alsafi, N. O'Neill, M. Khan, A. Kerwan, A. Al-Jabir, C. Iosifidis, R. Agha, World Health Organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19), *Int. J. Surg.* 76 (2020) 71–76.
- [2] W.H. Organization, World Health Organization Coronavirus Disease (COVID-19) Dashboard, World Health Organization, 2020.
- [3] R. Salimi, R. Gomar, B. Heshmati, The COVID-19 outbreak in Iran, *Journal of global health* 10 (1) (2020).
- [4] D.L. Crosby, A. Sharma, Insights on otolaryngology residency training during the COVID-19 pandemic, *Otolaryngology-Head Neck Surg. (Tokyo)* 163 (1) (2020) 38–41.
- [5] H.-M. Hau, J. Weitz, U. Bork, Impact of the COVID-19 pandemic on student and resident teaching and training in surgical oncology, *J. Clin. Med.* 9 (11) (2020) 3431.
- [6] A.R. Abedi, F. Aliakbari, S. Ghiasi, F. Allameh, M.A. Ghanbari, The impact of the first Covid 19 pandemic on urology residency training in Iran, *Men's Health J.* 4 (1) (2020) e21, e21.
- [7] D. Pertile, G. Gallo, F. Barra, A. Pasculli, P. Batistotti, M. Sparavigna, G. Vizzielli, D. Soriero, G. Graziano, S. Di Saverio, 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 Surg.* 72 (2) (2020) 269–280.
- [8] Y. Cai, A. Gulati, N.T. Jiam, K.C. Wai, E.A. Shuman, S.D. Pletcher, M.L. Durr, J. L. Chang, Evolving otolaryngology resident roles and concerns at the peak of the US COVID-19 pandemic, *Head Neck* 42 (12) (2020) 3712–3719.

- [9] Impact of the SARS-CoV-2 (COVID-19) crisis on surgical training: global survey and a proposed framework for recovery, *BJS open* 5 (2) (2021) zraa051.
- [10] T.H. Kamine, A. Rembisz, R.J. Barron, C. Baldwin, M. Kromer, Decrease in trauma admissions with COVID-19 pandemic, *West. J. Emerg. Med.* 21 (4) (2020) 819.
- [11] C.H. Williams, E.M. Scott, J.D. Dorfman, B.J. Simon, Traumatic injury under CoViD-19 stay-at-home advisory: experience of a New England trauma center, *J. Surg. Res.* 269 (2022) 165–170.
- [12] M.H. Lee, S.-R. Jang, T.-K. Lee, Comparative analysis of COVID-19 outbreak and changes in neurosurgical emergency patients, *J. Kor. Neurosurg. Soc.* 65 (1) (2022) 130.
- [13] W. Choi, H. Kim, W.S. Son, S. Sakong, J.-M. Cho, N.-J. Choi, T.-W. Noh, N. Kim, J.-W. Cho, J.-K. Oh, The impact of coronavirus disease 2019 on trauma patients and orthopaedic trauma operations at a single focused training center for trauma in South Korea, *J. Kor. Soc. Traumatol.* (2021).
- [14] G.M. Berg, R.J. Wyse, J.L. Morse, J. Chipko, J.M. Garland, A. Slivinski, M. Lieser, S. Biswas, M.M. Carrick, H. Rhodes, Decreased adult trauma admission volumes and changing injury patterns during the COVID-19 pandemic at 85 trauma centers in a multistate healthcare system, *Trauma Surg. Acute Care Open* 6 (1) (2021), e000642.
- [15] C.E. Pelzl, K. Salottolo, K. Banton, R.M. Madayag, D. Hamilton, T.M. Duane, M. Carrick, M. Lieser, G. Berg, D. Bar-Or, COVID-19 and trauma: how social distancing orders altered the patient population using trauma services during the 2020 pandemic, *Trauma Surg. Acute Care Open* 6 (1) (2021), e000645.
- [16] B. İlhan, G. Bozdereli Berikol, H. Aydin, M. Arslan Erduhan, H. Doğan, COVID-19 outbreak impact on emergency trauma visits and trauma surgery in a level 3 trauma center, *Ir. J. Med. Sci.* (2021) 1–6, 1971-.
- [17] S. Lund, T. MacArthur, M.M. Fischmann, J. Maroun, J. Dang, J.R. Markos, M. Zielinski, D. Stephens, Impact of COVID-19 Governmental Restrictions on Emergency General Surgery Operative Volume and Severity, *The American Surgeon*, 2021, 00031348211011113.
- [18] M.J. McGuinness, C. Harmston, N.R.T. Network, Association between COVID-19 public health interventions and major trauma presentation in the northern region of New Zealand, *ANZ J. Surg.* 91 (4) (2021) 633–638.
- [19] S. Jacob, D. Mwangi, I. Thakur, A. Moghadam, T. Oh, J. Hsu, Impact of societal restrictions and lockdown on trauma admissions during the COVID-19 pandemic: a single-centre cross-sectional observational study, *ANZ J. Surg.* 90 (11) (2020) 2227–2231.
- [20] D.R.W. MacDonald, D.W. Neilly, P.S.E. Davies, C.R. Crome, B. Jamal, S.L. Gill, A. C. Jariwala, I.M. Stevenson, G.P. Ashcroft, S. authors, Effects of the COVID-19 lockdown on orthopaedic trauma: a multicentre study across Scotland, *Bone Joint Open* 1 (9) (2020) 541–548.
- [21] G.J.J. van Aert, L. van der Laan, L.J.M. Boonman-de Winter, C.A.S. Berende, H.G. W. de Groot, P. Boele van Hensbroek, P.M.J. Schormans, M.B. Winkes, D.I. Vos, Effect of the COVID-19 pandemic during the first lockdown in The Netherlands on the number of trauma-related admissions, trauma severity and treatment: the results of a retrospective cohort study in a level 2 trauma centre, *BMJ Open* 11 (2) (2021), e045015.
- [22] S.-Y. Chen, H.-Y. Lo, S.-K. Hung, What is the impact of the COVID-19 pandemic on residency training: a systematic review and analysis, *BMC Med. Educ.* 21 (1) (2021) 1–18.
- [23] D.E. Bregman, T. Cook, C. Thorne, Estimated national and regional impact of COVID-19 on elective case volume in aesthetic plastic surgery, *Aesthetic Surg. J.* 41 (3) (2021) 358–369.
- [24] P. Lewicki, S.P. Basourakos, B.A.H. Al Awamlh, X. Wu, J.C. Hu, P.N. Schlegel, J. E. Shoag, Estimating the impact of COVID-19 on urology: data from a large nationwide cohort, *Eur. Urol. Open Sci.* 25 (2021) 52–56.
- [25] R.L. Donovan, T. Tilston, R. Frostick, T. Chesser, 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* 12 (10) (2020).
- [26] J.A. Khusid, M. Kashani, L.E. Fink, C.S. Weinstein, M. Gupta, The impact of the COVID-19 pandemic on urology residents: a narrative review, *Curr. Urol. Rep.* 22 (9) (2021) 1–9.
- [27] H.K. James, G.T.R. Pattison, Disruption to surgical training during Covid-19 in the United States, United Kingdom, Canada, and Australasia: a rapid review of impact and mitigation efforts, *J. Surg. Educ.* 78 (1) (2021) 308–314.
- [28] E.M. White, M.P. Shaughnessy, A.C. Esposito, M.D. Slade, M. Korah, P.S. Yoo, Surgical education in the time of COVID: understanding the early response of surgical training programs to the novel coronavirus pandemic, *J. Surg. Educ.* 78 (2) (2021) 412–421.
- [29] H. Aziz, T. James, D. Remulla, L. Sher, Y. Genyk, M.E. Sullivan, M.R. Sheikh, Effect of COVID-19 on surgical training across the United States: a national survey of general surgery residents, *J. Surg. Educ.* 78 (2) (2021) 431–439.
- [30] P.D. Megaloiikonomos, M. Thaler, V.G. Igoumenou, T. Bonanzinga, M. Ostojic, A. F. Couto, J. Diallo, I. Khosravi, Impact of the COVID-19 pandemic on orthopaedic and trauma surgery training in Europe, *Int. Orthop.* 44 (9) (2020) 1611–1619.
- [31] C.E. Wise, S. Berekyei Merrell, M. Sasnal, J.D. Forrester, M.T. Hawn, J.N. Lau, D. T. Lin, I.S. Schmiederer, D.A. Spain, A.K. Nassar, L.M. Knowlton, COVID-19 impact on surgical resident education and coping, *J. Surg. Res.* 264 (2021) 534–543.
- [32] A.N. Al-Ahmari, A.M. Ajlan, K. Bajunaid, N.M. Alotaibi, H. Al-Habib, A.J. Sabbagh, A.F. Al-Habib, S.S. Baesa, Perception of neurosurgery residents and attendings on online webinars during COVID-19 pandemic and implications on future education, *World Neurosurg.* 146 (2021) e811–e816.
- [33] A.A. Essilfie, E.T. Hurley, E.J. Strauss, M.J. Alaia, Resident, fellow, and attending perception of E-learning during the COVID-19 pandemic and implications on future orthopaedic education, *JAAOS J. Am. Acad. Orthopaed. Surg.* 28 (19) (2020).
- [34] T. Rana, C. Hackett, T. Quezada, A. Chaturvedi, V. Bakalov, J. Leonardo, S. Rana, Medicine and surgery residents' perspectives on the impact of COVID-19 on graduate medical education, *Med. Educ. Online* 25 (1) (2020), 1818439.
- [35] S. Balvardi, M. Alhshemi, J. Cipolla, L. Lee, J.F. Fiore, L.S. Feldman, The impact of the first wave of the COVID-19 pandemic on the exposure of general surgery trainees to operative procedures, *Surg. Endosc.* (2022) 1–7.
- [36] M. Papapanou, E. Routsis, K. Tsamakidis, L. Fotis, G. Marinou, I. Lidoriki, M. Karamanou, T.G. Papaioannou, D. Tsiptsios, N. Smyrnis, Medical education challenges and innovations during COVID-19 pandemic, *Postgrad. Med. J.* 98 (2022) 321–327.
- [37] E. Edigin, P.O. Eseaton, H. Shaka, P.E. Ojemolun, I.R. Asemota, E. Akuna, Impact of COVID-19 pandemic on medical postgraduate training in the United States, *Med. Educ. Online* 25 (1) (2020), 1774318.
- [38] M.H. Rajab, A.M. Gazal, K. Alkattan, Challenges to online medical education during the COVID-19 pandemic, *Cureus* 12 (7) (2020).
- [39] C. Zoia, G. Raffa, T. Somma, G.M. Della Pepa, G. La Rocca, M. Zoli, D. Bongetta, O. De Divitiis, M.M. Fontanella, COVID-19 and neurosurgical training and education: an Italian perspective, *Acta Neurochir.* 162 (8) (2020) 1789–1794.
- [40] S. Sabharwal, J.R. Ficke, D.M. LaPorte, How we do it: modified residency programming and adoption of remote didactic curriculum during the COVID-19 pandemic, *J. Surg. Educ.* 77 (5) (2020) 1033–1036.
- [41] T. Adesoye, C. Davis, H. Del Calvo, A. Shaikh, V. Chegiredy, E. Chan, S. Martinez, K. Pei, F. Zheng, N. Tariq, Optimization of surgical resident safety and education during the COVID-19 pandemic—lessons learned, *J. Surg. Educ.* 78 (1) (2021) 315–320.
- [42] F. Figueroa, D. Figueroa, R. Calvo-Mena, F. Narvaez, N. Medina, J. Prieto, Orthopedic surgery residents' perception of online education in their programs during the COVID-19 pandemic: should it be maintained after the crisis? *Acta Orthop.* 91 (5) (2020) 543–546.
- [43] R.C. Chick, G.T. Clifton, K.M. Peace, B.W. Propper, D.F. Hale, A.A. Alseidi, T. J. Vreeland, Using technology to maintain the education of residents during the COVID-19 pandemic, *J. Surg. Educ.* 77 (4) (2020) 729–732.
- [44] T.M. Coe, K.M. Jogerst, N.M. Sell, D.J. Cassidy, C. Eurboonyanun, D. Gee, R. Phitayakorn, E. Petrusa, Practical techniques to adapt surgical resident education to the COVID-19 era, *Ann. Surg.* 272 (2) (2020) e139.
- [45] A. Dedeilia, M.G. Sotiropoulos, J.G. Hanrahan, D. Janga, P. Dedeilias, M. Sideris, Medical and Surgical Education Challenges and Innovations in the COVID-19 Era: a Systematic Review, *in Vivo*, vol. 34, 2020, pp. 1603–1611, 3 suppl.
- [46] H. ElHawary, A. Salimi, P. Alam, M.S. Gilardino, Educational alternatives for the maintenance of educational competencies in surgical training programs affected by the COVID-19 pandemic, *J. Med. Educ. Curricular Dev.* 7 (2020), 2382120520951806.
- [47] T. McKechnie, M. Levin, K. Zhou, B. Freedman, V.N. Palter, T.P. Grantcharov, Virtual surgical training during COVID-19: operating room simulation platforms accessible from home, *Ann. Surg.* 272 (2) (2020) e153.
- [48] H. Ehrlich, M. McKenney, A. Elkbuli, We asked the experts: virtual learning in surgical education during the COVID-19 pandemic—shaping the future of surgical education and training, *World J. Surg.* 44 (7) (2020) 2053–2055.
- [49] R. Laloo, A. Giorgia, A. Williams, C.S. Biyani, M. Yiasemidou, Virtual surgical education for core surgical trainees in the Yorkshire deanery during the COVID-19 pandemic, *Scot. Med. J.* 65 (4) (2020) 138–143.
- [50] S. Yang, C. Jin, J. Wang, X. Xu, The use of social media to deliver surgical education in response to the COVID-19 pandemic, *J. Invest. Surg.* (2022) 1–7.
- [51] A. Arezzo, A. Vignali, C.A. Ammirati, R. Brodie, Y. Mintz, Is it possible to continue academic teaching in surgery during the COVID pandemic era? *Minim Invasive Ther. Allied Technol.* 31 (4) (2022) 487–495.
- [52] F. Tuma, M.K. Kamel, S. Shebrain, M. Ghanem, J. Blebea, Alternative surgical training approaches during COVID-19 pandemic, *Anna. Med. Surg.* 62 (2021) 253–257.