Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
OBJECTIVE: The impact of the coronavirus disease 2019 (COVID-19) pandemic has led to a significant transformation in medical practice and training. This nationwide survey study aims to evaluate the 1-year impact of the pandemic on training of neurosurgical residents.

METHODS: A 38-question Web-based survey was sent to 356 neurosurgery residents. Two hundred and thirty-five participated in the study (66% response rate), representing more than half of all neurological residents in the country.

RESULTS: Assignment to direct COVID-19 medical care was common (85.5%). Many of the neurosurgery residents (37.9%) were tested positive for COVID-19. Almost half of the respondents reported a decrease in work hours. Most participants (84.3%) reported a decline in total operative case volume (mean change, $-29.1\% \pm 1.6\%$), largely as a result of a decrease in elective ($-33.2\% \pm 1.6\%$) as opposed to emergency cases ($-5.1\% \pm 1.8\%$). For theoretic education, most respondents (54.9%) indicated a negative impact, whereas 25.1% reported a positive impact. For practical training, most respondents (78.7%) reported an adverse effect. A decrease in elective surgical case volume predicted a positive impact on theoretic training but a negative impact on practical training. Research productivity was reported by 33.2% to have decreased and by 23% to have increased. Forty-two percent indicated an increase in concerns about their training and career, with a negative impact on practical training being the most important predictor. Most (57.4%) had considered extending residency training to overcome negative effects of the pandemic.

CONCLUSIONS: COVID-19 has had a significant impact on neurosurgical practice and training. Effective measures should be used to mitigate these effects and better prepare for the future challenges.

INTRODUCTION

The World Health Organization declared coronavirus disease 2019 (COVID-19), the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, as a global pandemic on March 12, 2020. As of March 28, 2021, >125 million cases and 2.7 million deaths had been confirmed globally. Despite strict measures and the beginning of vaccination, the impact of the pandemic continues to increase. Ranked ninth in the world, Turkey has been among the most affected countries, with >3 million infected cases and 30,000 deaths, as of March 28, 2021. COVID-19 has brought unprecedented challenges to medicine and society. Health care systems around the world were largely unprepared to tackle the increasing number of cases. Governments and health care systems have been forced to expand their intensive care unit (ICU) and specialized inpatient ward capacities and redistribute the resources to fulfill the increasing demand.

Key words
COVID-19
Neurosurgery
Pandemic
Practice
Residency
Research
Training

Abbreviations and Acronyms
CI: Confidence interval
COVID-19: Coronavirus disease 2019
ICU: Intensive care unit
OR: Odds ratio
TRH: Training and research hospital
UH: University hospital

From the 1Department of Neurosurgery, Sisli Hamidiye Etfal Training and Research Hospital, University of Health Sciences, Sisli, Istanbul; and 2Department of Neurosurgery, Hacettepe University Faculty of Medicine, Sihhiye, Ankara, Turkey
To whom correspondence should be addressed: Sahin Hanalioglu, M.D., Ph.D. [E-mail: hanalioglu@hacettepe.edu.tr]

Citation: World Neurosurg. (2021) 151:e857-e870.
https://doi.org/10.1016/j.wneu.2021.04.137
Journal homepage: www.journals.elsevier.com/world-neurosurgery
Available online: www.sciencedirect.com
1878-8750/$ - see front matter © 2021 Elsevier Inc. All rights reserved.
The heavy impact of the pandemic on health care services has led to urgent and long-term revisions of health care systems. COVID-19 has also caused a deep change in the means of teaching and learning, and its impact is expected to be long-lasting. Combining service and training, medical and surgical residency programs have also faced significant challenges and have been restructured to meet the needs of their hospitals and communities.

Neurosurgery training programs are no exception. Several studies have explored the impact of COVID-19 pandemic on neurosurgical training programs. However, most of these studies investigated the early impact of the pandemic and focused solely on the educators’ perspectives. Only a few of these studies present the viewpoints of neurosurgery residents. To the best of our knowledge, this is the first study to evaluate the 1-year impact of the pandemic on the training of neurosurgical residents, who struggle to receive proper training and meet the challenge of the COVID-19 pandemic at the same time. We believe that the results of this study will help to identify better solutions to the problems arising in the training of future neurosurgeons worldwide.

**METHODS**

**Study Design**

A 38-question Web-based survey was administered to neurosurgical residents from January 25 to February 1, 2021 via the Google Forms platform (Google LLC, Mountain View, California, USA). Of 435 registered neurosurgical residents across Turkey, 356 (81.8%) were invited by telephone call or messages to participate in this survey. A Web-link of the survey was sent through e-mail or messaging services. A total of 235 unique responses were recorded and evaluated after removing duplicate and incomplete answers, yielding a 66% response rate. Overall, this cohort represented more than half (54%) of all neurosurgical residents in Turkey (Figure 1).

**Survey**

This survey included 5 sections: I) baseline information about residents and institutions (4 questions); II) COVID-19 duties and impact of pandemic on time management (7 questions); III) neurosurgical patient services during pandemic (6 questions); IV) resident training and research during pandemic; a) theoretic (knowledge) (7 questions), b) practical (skill) (8 questions), and c) research (2 questions); and V) concerns and thoughts for residency training (4 questions) (Table 1).

The participants were asked to answer the questions considering the entire period of the COVID-19 pandemic from its beginning until the time that the survey was completed. This strategy allowed us to evaluate the 1-year impact of the pandemic instead of early or short-term effects.

**Statistics**

Statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, New York, USA). Data are presented as mean ± standard deviation for parametric, median (range) for nonparametric continuous, and percent for categorical variables. A Student t test was used for continuous, and χ² and Fisher exact tests were used for categorical variables to compare between 2 groups. A Spearman correlation was used to measure the degree of association between 2 variables. Multivariate logistic regression was used to show independent predictors. A P value <0.05 was considered statistically significant.

![Figure 1. Geographic distribution of the survey participants.](image-url)
### Table 1. Survey Questions and Summary of the Responses

| Sections and Questions | Answers, n (%) |
|------------------------|----------------|
| **Section I. Baseline Information About Residents and Institutions** | |
| 1. What is the category of your training institution? | |
| University hospital | 115 (48.9) |
| Training and research hospital | 120 (51.1) |
| 2. In which city are you in training? | |
| Istanbul | 99 (42.1) |
| Ankara | 51 (21.7) |
| Izmir | 15 (6.4) |
| Samsun | 11 (4.7) |
| Adana | 8 (3.4) |
| Other | 51 (21.7) |
| 3. Which year of neurosurgical residency are you in? | |
| First year | 40 (17) |
| Second year | 61 (26) |
| Third year | 53 (22.6) |
| Fourth year | 30 (12.8) |
| Fifth year | 43 (18.3) |
| Sixth year | 8 (3.4) |
| 4. What was the annual case volume in your institution at the prepandemic period? | |
| <500 | 8 (3.4) |
| 500—1000 | 60 (25.5) |
| 1000—1500 | 76 (32.3) |
| 1500—2000 | 45 (19.1) |
| >2000 | 46 (19.6) |
| **Section II. Impact of COVID-19 on Personal Health and Clinical Duties Related to COVID-19** | |
| 5. Have you been assigned to work in dedicated COVID-19 facilities (ICU, ward, clinic)? | |
| Yes | 201 (85.5) |
| No | 34 (14.5) |
| 6. If you have been assigned, have you received adequate training on the evaluation and management of COVID-19 cases (swabbing, treatment algorithms etc)? | |
| Yes | 123 (52.3) |
| No | 96 (40.9) |
| 7. What was the total duration of your assignment in COVID-19 facilities? | |
| <15 days | 16 (6.8) |
| 15—30 days | 66 (28.1) |
| 30—45 days | 29 (12.3) |

**Table 1. Continued**

| Sections and Questions | Answers, n (%) |
|------------------------|----------------|
| 8. Have you ever been absent from work because of isolation with the diagnosis/suspicion/high-risk contact of COVID-19? | |
| No | 103 (43.8) |
| Yes, because of diagnosis of COVID-19 | 89 (37.9) |
| Yes, because of suspicion or high-risk contact of COVID-19 | 43 (18.3) |
| 9. What was the duration of absence from work because of diagnosis or suspicion of COVID-19? | |
| ≤10 days | 62 (26.4) |
| 10—20 days | 58 (24.7) |
| 20—30 days | 15 (6.4) |
| >30 days | 5 (2.1) |
| 10. During the pandemic, has the flexible working hours regime been implemented in your institution for residents? | |
| Not implemented at all | 52 (22.1) |
| Implemented partially for short-term | 160 (68.1) |
| Implemented partially for long-term | 13 (5.5) |
| Fully implemented | 10 (4.3) |
| 11. How has your weekly time spent in the hospital changed during the pandemic compared with the prepandemic period? | |
| Considerably decreased (>50%) | 10 (4.3) |
| Moderately decreased (25%—50%) | 33 (14) |
| Slightly decreased (10%—25%) | 72 (30.6) |
| Unchanged (±10%) | 85 (36.2) |
| Slightly increased (10%—25%) | 18 (7.7) |
| Moderately increased (25%—50%) | 14 (6) |
| Considerably increased (>50%) | 3 (1.3) |
| 12. How has the total number of operative cases in your institution changed during the pandemic compared with the prepandemic period? | |
| Considerably decreased (>50%) | 51 (21.7) |
| Moderately decreased (25%—50%) | 82 (34.9) |
| Slightly decreased (10%—25%) | 65 (27.7) |
| Unchanged (±10%) | 24 (10.2) |
| Slightly increased (10%—25%) | 8 (3.1) |
| Moderately increased (25%—50%) | 4 (1.7) |

3D, three-dimensional; VR/AR, virtual reality/augmented reality.
| Sections and Questions | Answers, n (%) |
|------------------------|---------------|
| 13. How has the number of elective operative cases in your institution changed during the pandemic compared with the prepandemic period? | |
| Considerably increased (>50%) | 1 (0.4) |
| Moderately decreased (25%−50%) | 79 (33.6) |
| Slightly decreased (10%−25%) | 62 (26.4) |
| Unchanged (±10%) | 65 (27.7) |
| Slightly increased (10%−25%) | 20 (8.5) |
| Moderately increased (25%−50%) | 2 (0.4) |
| Considerably increased (>50%) | 1 (0.4) |

14. How has the number of emergency operative cases in your institution changed during the pandemic compared with the prepandemic period? |
| Considerably decreased (>50%) | 14 (6) |
| Moderately decreased (25%−50%) | 37 (15.7) |
| Slightly decreased (10%−25%) | 46 (19.6) |
| Unchanged (±10%) | 77 (32.8) |
| Slightly increased (10%−25%) | 32 (13.6) |
| Moderately increased (25%−50%) | 21 (8.9) |
| Considerably increased (>50%) | 8 (3.4) |

15. How has the number of intensive care unit cases in your institution changed during the pandemic compared with the prepandemic period? |
| Considerably decreased (>50%) | 26 (11.1) |
| Moderately decreased (25%−50%) | 36 (15.3) |
| Slightly decreased (10%−25%) | 51 (21.7) |
| Unchanged (±10%) | 84 (35.7) |
| Slightly increased (10%−25%) | 26 (11.1) |
| Moderately increased (25%−50%) | 6 (2.8) |
| Considerably increased (>50%) | 6 (2.8) |

16. How has the number of inpatient (floor) cases in your institution changed during the pandemic compared with the prepandemic period? |
| Considerably decreased (>50%) | 42 (17.9) |
| Moderately decreased (25%−50%) | 67 (28.5) |
| Slightly decreased (10%−25%) | 79 (33.6) |
| Unchanged (±10%) | 39 (16.6) |
| Slightly increased (10%−25%) | 6 (2.6) |
| Moderately increased (25%−50%) | 0 (0) |
| Considerably increased (>50%) | 2 (0.9) |

Continues
Table 1. Continued

| Sections and Questions | Answers, n (%) |
|------------------------|----------------|
| Completely face to face | 26 (11.1) |
| Online + face to face  | 69 (29.4) |
| Completely online      | 50 (21.3) |
| Not held at all        | 90 (38.3) |

22. How many hours per week on average could you devote to online seminars and courses except your departmental teaching sessions during the pandemic?
   - Not attended at all: 37 (15.7)
   - <1 hour: 73 (31.1)
   - 1–3 hours: 84 (35.7)
   - 3–5 hours: 28 (11.9)
   - >5 hours: 13 (5.5)

23. What are your opinions about online training and meetings during the pandemic?
   - Not beneficial at all: 17 (7.2)
   - Less beneficial than face-to-face training: 81 (34.5)
   - As beneficial as face-to-face training: 89 (37.9)
   - More beneficial than face-to-face training: 48 (20.4)

24. How many hours per week on average could you devote to self-directed learning (reading textbooks and articles, etc.) during the pandemic?
   - Not at all: 29 (12.3)
   - <1 hour: 56 (23.8)
   - 1–3 hours: 80 (34)
   - 3–5 hours: 38 (16.2)
   - >5 hours: 32 (13.6)

b. Practical (skill) training

25. How has your surgical (practical) training been affected by the pandemic, compared with the prepandemic period?
   - Considerably negative: 59 (25.1)
   - Moderately negative: 70 (29.8)
   - Slightly negative: 56 (23.8)
   - Unchanged: 41 (17.4)
   - Slightly positive: 5 (2.1)
   - Moderately positive: 2 (0.9)
   - Considerably positive: 2 (0.9)

26. If your surgical (practical) training has been negatively affected, what do you think would be the reason(s)? (you can choose >1 option)
   - Decreased operative case diversity: 91 (38.7)
   - Decreased operative case volume: 143 (60.9)
   - Decreased weekly work hours in own department: 50 (22.3)

b. Practical (skill) training

27. If your surgical (practical) training has been positively affected, what do you think would be the reason(s)? (you can choose >1 option)
   - Increased operative case diversity: 1 (0.4)
   - Increased operative case volume: 5 (2.1)
   - Increased weekly work hours in own department: 5 (2.1)
   - Taking more active role in operations: 22 (9.4)
   - Increased motivation: 4 (1.7)

28. Which of the following tools are available for your surgical training in your institution? (You can choose >1 option)
   - Cadaver: 30 (12.8)
   - Training models (3D model, microanastomosis training kit, etc.): 19 (8.1)
   - Surgical simulator (VR/AR): 0 (0)
   - Experimental animal: 14 (6)
   - None: 185 (78.7)

29. For your surgical training, to what extent do you think practicing on cadaver can compensate the negative effects of the pandemic on surgical practice?
   - Not at all: 15 (6.4)
   - Slightly: 63 (26.8)
   - Moderately: 46 (19.6)
   - Considerably: 111 (47.3)

30. For your surgical training, to what extent do you think practicing on models can compensate the negative effects of the pandemic on surgical practice?
   - Not at all: 28 (11.9)
   - Slightly: 88 (37.4)
   - Moderately: 49 (20.9)
   - Considerably: 70 (29.9)

31. For your surgical training, to what extent do you think practicing on surgical simulator (VR/AR) can compensate the negative effects of the pandemic on surgical practice?
   - Not at all: 22 (9.4)
   - Slightly: 83 (35.3)
   - Moderately: 62 (26.4)
   - Considerably: 68 (28.9)

3D, three-dimensional; VR/AR, virtual reality/augmented reality.

Table 1. Continued

| Sections and Questions | Answers, n (%) |
|------------------------|----------------|
| Assignments in the COVID-19 services | 104 (44.3) |
| Interrupted training because of COVID-19 isolations | 47 (20) |
| Loss of motivation | 68 (28.9) |

27. If your surgical (practical) training has been positively affected, what do you think would be the reason(s)? (you can choose >1 option)
   - Increased operative case diversity: 1 (0.4)
   - Increased operative case volume: 5 (2.1)
   - Increased weekly work hours in own department: 5 (2.1)
   - Taking more active role in operations: 22 (9.4)
   - Increased motivation: 4 (1.7)

28. Which of the following tools are available for your surgical training in your institution? (You can choose >1 option)
   - Cadaver: 30 (12.8)
   - Training models (3D model, microanastomosis training kit, etc.): 19 (8.1)
   - Surgical simulator (VR/AR): 0 (0)
   - Experimental animal: 14 (6)
   - None: 185 (78.7)

29. For your surgical training, to what extent do you think practicing on cadaver can compensate the negative effects of the pandemic on surgical practice?
   - Not at all: 15 (6.4)
   - Slightly: 63 (26.8)
   - Moderately: 46 (19.6)
   - Considerably: 111 (47.3)

30. For your surgical training, to what extent do you think practicing on models can compensate the negative effects of the pandemic on surgical practice?
   - Not at all: 28 (11.9)
   - Slightly: 88 (37.4)
   - Moderately: 49 (20.9)
   - Considerably: 70 (29.9)

31. For your surgical training, to what extent do you think practicing on surgical simulator (VR/AR) can compensate the negative effects of the pandemic on surgical practice?
   - Not at all: 22 (9.4)
   - Slightly: 83 (35.3)
   - Moderately: 62 (26.4)
   - Considerably: 68 (28.9)

3D, three-dimensional; VR/AR, virtual reality/augmented reality.
Table 1. Continued

| Sections and Questions                                                                 | Answers, n (%)                      |
|----------------------------------------------------------------------------------------|-------------------------------------|
| 32. For our surgical training, to what extent do you think practicing on experimental animals can compensate the negative effects of the pandemic on surgical practice? | Not at all 51 (21.7) Slightly 74 (31.5) Moderately 50 (21.3) Considerably 60 (25.5) |
| 33. Have you been actively involved in any scientific research during the pandemic?    | Yes 95 (40.4) No 140 (59.6)         |
| 34. How has your research productivity been affected by the pandemic, compared with the prepandemic period? | Considerably decreased (>50%) 35 (14.9) Moderately decreased (25%–50%) 20 (8.5) Slightly decreased (10%–25%) 23 (9.8) Unchanged (±10%) 103 (43.8) Slightly increased (10%–25%) 35 (14.9) Moderately increased (25%–50%) 11 (4.7) Considerably increased (>50%) 8 (3.4) |

Section V: Concerns and Thoughts for Residency Training

35. Has the pandemic affected your concerns about residency training and future career?
   - I have no concerns 52 (22.1)
   - Decreased my concerns 2 (0.9)
   - Not changed my concerns 82 (34.9)
   - Increased my concerns 99 (42.1)

36. Would you prefer if you were given the right to extend the residency training duration for up to 6 months because of the pandemic?
   - No, I wouldn’t extend my residency training duration 162 (68.9)
   - Yes, I would extend my residency training duration 73 (31.1)

37. If your preference to extend your residency training duration was “Yes”, why do you think it might be useful?
   - Beneficial for theoretic education 2 (0.9)
   - Beneficial for surgical (practical) training 36 (15.3)
   - Beneficial for both of them 45 (19.1)

38. If your preference to extend your residency training duration was “No”, would you change your mind if the pandemic continues in 2021 as intensely as in 2020?
   - No, I wouldn’t extend my residency training duration 100 (42.6)
   - Maybe, I could consider extending my residency training duration 55 (23.4)
   - Yes, I would definitely extend my residency training duration 7 (3)

Table 1. Continued

| Sections and Questions                                                                 | Answers, n (%)                      |
|----------------------------------------------------------------------------------------|-------------------------------------|
| 39. Has the pandemic affected your concerns about residents’ and future career?        | Yes, I would definitely extend my residency training duration 7 (3) |

RESULTS

A detailed account of the survey questions and distribution of the responses is presented in Table 1.

Section I: Baseline Information About Residents and Institutions

Study participants (n = 235) represented 54% of all neurological residents (n = 435) in Turkey. Participants were enrolled in neurosurgical specialty training in 24 different cities and 51 institutions, representing 68.6% of all 35 cities and 73.6% of all 69 institutions with active neurosurgical training programs in the country (Figure 1). The number of participants in the university hospitals (UHs) (autonomous) and training and research hospitals (TRHs) (governed by the Ministry of Health) were similar (115 in UHs and 120 TRHs) (Figure 2). Study participants were evenly distributed across all years in training from 1 to 6, although junior residents represented the majority (Figure 2). Although the participants were from 24 cities, 78.3% were from 5 major cities that host more than half of all neurological training programs and two thirds of all neurological residents (Figure 1). The study cohort included not only programs with low annual case volume (<1000 cases/year, 28.0%) but also high annual case volume (>2000 cases/year, 19.6%), although most participants were from the programs with a medium annual case volume (1000–2000 cases/year, 51.4%).

Section II: Impact of COVID-19 on Personal Health and Clinical Duties Related to COVID-19

Two hundred and one residents (85.7%) had been assigned to the COVID-19 assignment. Seventy-five residents (31.9%) spent 2 months in most flexible working hours for most public workers, neurosurgical residents seemed to minimally, if at all, benefit from flexible working schemes. Most of the participants (68.1%) reported that these

3D, three-dimensional; VR/AR, virtual reality/augmented reality.
Figure 2. Distribution of participants across years in training and institution categories. PGY, postgraduate year; TRH, training and research hospital; UH, university hospital.

Figure 3. Changes in neurosurgical operative case volumes during the pandemic compared with the prepandemic period.
regulations were applied only partially and short-term in their departments. On the other hand, 48.9% reported that their weekly time spent in the hospital decreased, whereas 36.2% indicated that it did not change during the pandemic compared with the prepandemic period. On average, an 8.8% ± 1.5% decrease was noted in the weekly time spent in the hospital.

Section III: Neurosurgical Patient Services During Pandemic
During the pandemic, 198 participants (84.3%) reported a decrease in the total number of the operative cases in their institution. Overall, the average percent change was −29.1% ± 1.6% (decrease) for total operative cases. This decrease was mostly caused by the decrease in the number of elective cases (−33.2% ± 1.6%) as opposed to emergency cases (−5.1% ± 1.8%). In addition, a decrease to any extent in the number of elective cases was reported by 87.7%, whereas for emergency cases, it was noted by 41.3% of the participants (Figure 3). Average numbers of patients in neurosurgical ICU (−11.6% ± 1.7%), inpatient floors (−26.3% ± 1.4%), and outpatient clinics (−24.6% ± 1.5%) were also reported to decrease in this period. The decrease in numbers was reported as 48.1% for ICU cases, 80% for inpatient cases, and 77% for outpatient cases. Although the number of neurosurgical patients (or beds) seems to decrease in all 3 categories, the ICU cases seemed to be less affected than inpatient and outpatient cases (Figure 4).

Section IV: Resident Training and Research During Pandemic
Theoretic Training and Academic Sessions. More than half of the residents (n = 129, 54.9%) indicated that their theoretic education was negatively affected, whereas 59 residents (25.1%) reported a positive impact. A negative impact on theoretic training was believed to be caused by cancellation/interruption of departmental teaching sessions (n = 117, 49.8%), diminished attendance at other academic conferences and training courses (n = 98, 41.7%), clinical assignment in the COVID-19 services (n = 52, 22.1%), loss of motivation (n = 46, 19.6%), and decreased weekly work hours in own department (n = 32, 13.6%). Nevertheless, an increase in the number and availability of online training opportunities (n = 62, 26.4%) as well as the time allocated to self-training (n = 57, 24.3%) was considered to have a positive impact on theoretic education of residents. Departmental teaching sessions were shifted toward online sessions in about half of the participants’ institutions (online and face to face, n = 69, 29.4%; completely online, n = 50, 21.3%). On the other hand, 26 participants (11.1%) reported that their
academic sessions were performed completely face to face, whereas 90 residents (58.3%) had no academic teaching sessions at all during the pandemic. Almost half of the residents (n = 110, 46.8%) had spent <1 hour per week and only 41 residents (17.4%) spent >3 hours/week on online seminars and courses outside their own training program. However, most of the participants (n = 137, 58.3%) believed that online academic sessions were at least as beneficial as face-to-face sessions with a physical presence. Time devoted to resident self-directed learning was <1 hour/week in 36.2% (n = 83), 1–3 hours/week in 34% (n = 80), and >3 hours/week in 29.8% (n = 70).

COVID-19 assignment duration and time devoted to online training sessions and self-learning were positively correlated, whereas changes in weekly time spent in the neurosurgery department, the number of elective operative cases and inpatient cases, and cancellation/interruption of departmental teaching sessions were negatively correlated with the perceived impact on theoretic education of the residents (Table 2). Multivariate analysis showed that the decrease in weekly time spent in the neurosurgery department (odds ratio [OR], 0.737; 95% confidence interval [CI], 0.551–0.985; P = 0.037), decrease in number of elective operative cases (OR, 0.591; 95% CI, 0.359–0.975; P = 0.043), continuation of departmental teaching sessions (OR, 0.596; 95% CI, 0.438–0.811; P = 0.001), and increased time devoted to online training sessions (OR, 1.728; 95% CI, 1.252–2.384; P = 0.001) were independent predictors of the positive impact of pandemic on theoretic training.

Practical Training and Educational Tools for Skill Development. Most participants (n = 185, 78.7%) reported that their practical training was adversely affected by the pandemic. They attributed the negative effect to the decrease in number (n = 143, 60.9%) of diversity (n = 91, 38.7%) of operative cases; clinical assignment to COVID-19–related duties (n = 104, 44.3%), loss of motivation (n = 68, 28.0%), and decreased weekly work hours in own department (n = 50, 22.3%). However, relatively few of the residents (n = 22, 9.4%) considered that taking a more active role in operative cases had a positive effect on their surgical practice during the pandemic. Presence and usefulness of various educational tools for surgical skill development were also questioned. Most participants (n = 185, 78.7%) reported that none of the listed tools (surgical training model/kit, cadaver, experimental animal, or simulator) were available in their institution. Cadavers, simulators, and surgical training models/kits were perceived as the most useful tools to compensate the negative effects of the pandemic on surgical training.

Changes in weekly time spent in the neurosurgery department, total number of operative cases, number of elective operative cases, ICU cases, inpatient cases, and outpatient cases were all negatively correlated with the perceived impact on practical training of the residents (Table 2). In the multivariate analysis, change in total number of operative cases was the only independent predictor of the negative impact of pandemic on practical training (OR, 1.576; 95% CI, 1.186–2.093; P = 0.002).

| Table 2. Correlation Analysis of Various Factors in Relation to the Impact of the Pandemic on Training and Research |
|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| Impact on Theoretic  | Impact on Practical  | Impact on Research  |
| Training, r_s (P)   | Training, r_s (P)   | Productivity, r_s (P) |
|---------------------|---------------------|----------------------|
| Category of institution (university hospital vs. training and research hospital) | 0.009 (0.896) | −0.048 (0.459) | −0.122 (0.062) |
| Year in neurosurgical training | 0.120 (0.067) | 0.037 (0.572) | 0.216 (0.001) |
| Prepandemic case volume | 0.032 (0.625) | −0.037 (0.571) | 0.004 (0.986) |
| Duration of COVID-19 assignment | 0.191 (0.006) | −0.270 (<0.001) | −0.001 (0.986) |
| COVID-19 diagnosis or high-risk contact | −0.059 (0.365) | 0.069 (0.289) | −0.028 (0.668) |
| Duration of absence from neurosurgery department | 0.068 (0.422) | 0.028 (0.738) | −0.173 (0.041) |
| Change in weekly time spent in neurosurgery department | −0.150 (0.021) | 0.211 (0.001) | −0.105 (0.109) |
| Change in total number of operative cases | −0.126 (0.054) | 0.427 (0.000) | 0.065 (0.319) |
| Change in number of elective operative cases | −0.203 (0.002) | 0.379 (<0.001) | −0.009 (0.890) |
| Change in number of emergency operative cases | −0.116 (0.076) | 0.110 (0.093) | 0.055 (0.399) |
| Change in number of ICU cases | −0.583 (0.375) | 0.204 (0.002) | 0.064 (0.412) |
| Change in number of inpatient cases | −0.137 (0.036) | 0.342 (<0.001) | 0.043 (0.515) |
| Change in number of outpatient cases | −0.024 (0.713) | 0.197 (0.002) | 0.068 (0.301) |
| Cancellation/interruption of departmental teaching sessions | −0.415 (<0.001) | −0.052 (0.427) | −0.241 (<0.001) |
| Time devoted to online training sessions | 0.372 (<0.001) | 0.048 (0.461) | 0.325 (<0.001) |
| Time devoted to self-learning | 0.240 (<0.001) | 0.094 (0.149) | 0.289 (<0.001) |

Bold text indicates a statistically significant difference with a P-value less than 0.05.

r_s: Spearman correlation coefficient. P: statistical significance.
ICU: intensive care unit.
Research Productivity. Two thirds of the residents (n = 140, 59.6%) were not involved in any research during the pandemic. Compared with the prepandemic period, 103 residents (43.8%) reported that their academic productivity remained unchanged. Seventy-eight participants (33.2%) indicated a decline, whereas 54 (23%) reported an increase in their research productivity during the pandemic. Average percent change in research productivity was calculated as \(-7.5\%\pm1.9\%\).

Year in residency training and time devoted to online training sessions and self-learning were positively correlated, whereas cancellation/interruption of departmental teaching sessions was negatively correlated with the perceived impact on research of the residents (Table 2). In the multivariate analysis, category of institution (TRH) (OR, 0.313; 95% CI, 0.137—0.713; \(P = 0.006\)), cancellation/interruption of departmental teaching sessions (OR, 0.661; 95% CI, 0.452—0.967; \(P = 0.033\)) and less time devoted to online trainings (OR, 2.061; 95% CI, 1.341—3.168; \(P = 0.001\)) were independent predictors of the negative impact of pandemic on research productivity of the residents.

Section V: Concerns and Thoughts for Residency Training

Ninety-nine participants (42.1%) indicated an increase in their concerns regarding their current training and future career. Correlations analyses showed that change in total and elective operative cases, mode of institutional training sessions, and perceived impact on theoretic and practical training as well as research were negatively correlated with the perceived impact on research of the residents.
correlated with increased concerns (Table 3). Multivariate analysis showed that perceived negative impact on practical training was the single most important independent determinant of increased concerns (OR, 0.82; 95% CI, 0.446–0.759; \( P < 0.001 \)), whereas impact on theoretic training (OR, 0.857; 95% CI, 0.697–1.006; \( P = 0.058 \)) and research (OR, 0.820; 95% CI, 0.668–1.007; \( P = 0.059 \)) were also marginally significant factors.

In the last part, when asked whether they would request to extend their training duration for up to 6 months if given the right to do so, one third of the participants (\( n = 73 \)) replied positively. Change in time spent in the hospital, time spent in online training and seminars, impact on practical training, and change in anxiety level were correlated with the time extension choice in the first place. More than one third of those who did not want to extend residency training in the current situation indicated that they would consider an extension if the pandemic continued throughout 2021 or beyond. Institution type, year in residency, change in number of emergency operative cases, and total inpatient and outpatient cases were correlated with the decision for extension for the next year. More than half of the participants (57.4%) had considered extending their residency training to overcome negative effects of the pandemic on their specialty training. Preference for an extension seems to correlate with year in residency training, change in caseload (numbers of elective and emergency operative cases and inpatient and outpatient cases), concerns/anxiety levels, and impact on practical training, but not theoretic training and research.

**DISCUSSION**

The COVID-19 pandemic has had a tremendous impact on health care services and medical education. Neurosurgical training and practice have also faced challenges during the pandemic. In this study, we evaluated the 1-year impact of the pandemic on clinical practice, training, and research productivity of neurosurgical residents in Turkey from the trainees’ perspective. This period corresponds to one fifth of standard neurosurgical training (5 years) and thus has a significant effect on overall training of current residents. This is the first study to evaluate the impact of the COVID-19 pandemic on neurosurgical training at a national level in the relatively long-term. We show that the pandemic has had a negative overall impact on neurosurgical training, mostly because of a diminishing number of elective neurosurgical cases and nonneurosurgical clinical assignments related to COVID-19. Nevertheless, emerging learning opportunities such as online seminars and more time for self-learning seem to have had a positive impact, particularly on theoretic training.

**Baseline Information About Residents and Institutions**

With 235 respondents from 51 institutions in 24 cities, this study has a wide coverage and includes most neurosurgical residents in the country. A total of 435 residents are enrolled in 69 neurosurgical training programs in 35 cities in Turkey.\(^{10,17}\) The distribution of the participants across different cities and institutions confirmed good representation of national data. Two types of academic health care institutions, namely UHs (autonomous) and TRHs (governed by the Ministry of Health), are responsible for residency training in Turkey. Whereas TRHs were concentrated on a few major cities, UHs were widely distributed across the country. The numbers of respondents from the 2 categories of institution were similar (120 UHs and 115 TRHs). Also, years in residency training and annual case volume of the institutions showed homogenous distribution across categories. Most neurosurgical programs seem to have an annual case volume of between 1000 and 2000 operative cases/year.

**Direct Involvement in COVID-19 Medical Care and Impact on Personal Wellness**

Most neurosurgery residents were assigned to work in dedicated COVID-19 services for different periods. However, almost half of them received no or inadequate training relevant for evaluation and management of patients with COVID-19. Residents are an important part of the hospital workforce worldwide.\(^{18}\) Although they are entitled to receive proper training when becoming involved in clinical services within their specialty areas, most residents had to work outside their departments and at the forefront to take part in the challenge of COVID-19, especially during the peaks of the pandemic, like in other countries.\(^{19,20}\) Alhaj et al.\(^2\) reported that 82.7% of residents resumed their work at the hospital during the early phase of the pandemic despite stay-at-home orders. Likewise, our study showed that flexible work hours were not implemented properly for most residents. This fact possibly implies an inadequate implementation of other strategies such as dividing resident teams and in-house calls.\(^{21-24}\) This intensive work regime may have been responsible for the high rate of COVID-19 diagnosis (37.9%) among neurosurgical residents in Turkey. This rate is higher than the COVID-19 polymerase chain reaction positivity rate (7.3%) among health care workers found in a study from the United States in November 2020.\(^25\) On the other hand, World Health Organization global surveillance data showed that approximately 14%–19% of COVID-19 cases are among health care professionals.\(^26\) Our data along with others’ show that the percentage of health care professionals infected with COVID-19 is higher than that of their counterparts in other countries. Doctors at the forefront of the challenge of COVID-19 have a higher risk of infection and mortality caused by COVID-19.\(^27\) Our study also showed that beside these health risks, residents have also experienced adverse effects of COVID-19 on their specialty training as a result of reduced time for specialty-related clinical exposure.

**Neurosurgical Patient Services During the Pandemic**

Our study showed considerably decreased case numbers in neurosurgical practice during 1 year of the pandemic. Elective operative cases were reduced by 30%–35%, whereas emergency cases were only minimally decreased (5%). The number of neurosurgical cases seen in the inpatient wards and outpatient clinics also decreased markedly (25%–30%), whereas neurosurgical ICU cases were less affected (10%). In a global survey circulated among 444 neurosurgeons from 60 countries during the early phase of the COVID-19 outbreak, 52.5% of respondents reported that all elective cases were cancelled and clinics were closed, and 46.1% reported that the operative case volume decreased by >50% during the first peak of the pandemic.\(^28\)
Another study comparing case numbers between prepandemic and pandemic periods found that in April and May 2020, neurosurgical operative case volumes decreased by 58% and 20% compared with the same months of 2019. Field et al. reported similar decreases both in total (42%) and in elective (53%) surgical procedures in the early period of the pandemic in New York. A continental survey showed that there was even more severe reduction in elective surgery (−80%), clinics (−83%), and emergency surgery (−38.50%) in the African continent. It is believed that mobility restrictions and stay-at-home orders during the pandemic significantly reduced the number of individuals affected by craniospinal trauma. An early report from a tertiary referral center in New York reported a marked decrease in consultations for traumatic brain (22%) and spine (35%) injuries, and a similar study from Emory University (Atlanta) reported a 51% reduction of trauma case volume. However, taking into account a whole year with the COVID-19 pandemic instead of only early or peak pandemic periods, our findings suggest that neurosurgical emergency operative and ICU case volumes had only mildly (5%−10%) reduced compared with the prepandemic period. We believe that a larger nationwide decrease in neurological emergencies is still a possibility but might have been compensated in teaching hospitals because most emergencies were referred to tertiary centers (i.e., with neurosurgical training programs) because most secondary-level hospitals had shut down their operating rooms for longer periods during the pandemic. Nevertheless, elective operative case volume and the number of (elective) inpatient and outpatient cases decreased more significantly (25%−35%) in that period, implying a more conservative attitude toward elective neurological cases both in patients and in neurosurgeons, which lasted beyond lockdown periods. Pelagros et al. reported more severe reduction in inpatient and outpatient volumes (37.8%−44.6%) during the early phases of the pandemic in North American academic centers. It is possible that most institutions had resumed prepandemic case numbers in the later period of the pandemic. This theory should be explored to better evaluate the correlation among pandemic peaks, precautions, and neurosurgical practice.

Resident Training and Research During the Pandemic

Overall, neurosurgery residents reported a negative impact of the pandemic on their specialty training. As expected, practical (skill) training (78.7% negative) was more affected than theoretical education (54.9% negative). Of the respondents, 25.1% reported a positive impact on their theoretical education, whereas only 4% reported a positive impact for practical training during the pandemic. Reduced time/involve ment in neurosurgical patient services and decrease in case volumes are likely the root causes of this severe negative impact on practical training. In previous surveys of neurosurgery residents worldwide, respondents reported that their surgical training had been affected. During the early phase of the pandemic, Italian neurosurgery residents reported that almost all of those interviewed reduced their surgical activity (78.6% performed fewer operations and 16.1% did not perform any operation at all). Pelagros et al. reported that almost all North American neurosurgery residents had worked >60 hours per week in the prepandemic period, whereas two thirds of them had <60 work hours per week during the pandemic. Nevertheless, many residency programs have quickly adapted to the pandemic conditions and provided augmented didactic teaching to supplement the decline in hands-on training. Our multivariate analyses showed that decrease in operative case volumes, decrease in weekly work hours, increased time devoted to online training and self-learning, and continuation of departmental teaching sessions were associated with a positive impact on theoretical training.

Although the pandemic led to an increase in time devoted to didactic learning and self-study of the residents in our country similar to others, our study showed that it is still inadequate for most neurosurgical residents in Turkey. It is concerning that 38.3% of the respondents reported not having departmental academic sessions and almost half of the residents reported that they spent only 1 hour per week or less on online training sessions (e.g., webinars and courses). That there is no strict supervision of residency training and board certification for neurosurgery is not mandatory on a national level in Turkey could be the reasons for disregarding strong theoretic education. In comparison, more than half of the North American neurosurgical residents (58.6%) reported spending >4 hours per week in formal didactic lectures through their program during the pandemic.

The pandemic has also created new opportunities for training. Distant training has become the mainstay of education during the pandemic. Although not every department or national society has sufficient infrastructure or preparedness to provide online training, the pandemic has allowed access to a myriad of free online webinars and courses worldwide. Neurosurgical educators and trainees believed that conferences would be at least partly replaced by virtual conferences in the future. Likewise, in our study, 58.3% of the residents believed that online sessions were at least as beneficial as face-to-face conferences. Other educational tools should also be incorporated into surgical training to mitigate adverse effects of the pandemic. Although the current status is not satisfactory regarding the use of different training tools such as cadavers, 3D models, virtual reality/augmented reality, and simulators, the respondents of our survey valued these tools highly for their surgical training. It is likely that the pandemic along with the emergence of new technologies, public attention to patient safety, and new regulations within medical education will accelerate the adoption and use of these tools.

Research productivity has also been reported to increase during the pandemic. However, only 23% of the respondents reported an increase in their research productivity, whereas 43.8% indicated no change and 33.2% reported a decrease. Zoia et al. reported that the increased time availability outside neurosurgical departments resulted in an increased scientific activity of residents (55.7% of respondents). Training in UHs, continuation of departmental teaching sessions, and increased time devoted to online training and self-study were associated with a positive impact on research productivity. However, pre-pandemic level of resident involvement in academic research had already been lower in Turkey compared with North American and European counterparts, as shown by several studies.
Therefore, we believe that strong encouragement in research among neurosurgery residents should be a priority for program directors and neurosurgical societies.

**Concerns and Thoughts for Residency Training**

Of the participants, 42% indicated increased anxiety levels regarding their training and future career. Multivariate analysis showed that perceived negative impact on practical training was the single most important independent determinant of increased anxiety, whereas impact on theoretic training and research was also a marginally significant factor.

In a survey of North American neurosurgery residents, one third of the respondents were concerned that the pandemic would negatively affect their overall residency education, another one third were convinced that the course of their education would be unaltered, and the remaining one third were unsure of the long-term effects that the pandemic would have on their education. Senior residents were more likely than were the junior residents to report that their cumulative residency experience and future career prospects had been negatively influenced by the pandemic. However, in our study, year in training was not a significant factor. How to compensate for the negative effects of the pandemic on residency training is a matter of debate. Surgical video learning, laboratory training, simulators, fellowship programs, and extended stay in residency training are among the proposed methods for mitigation efforts. We also asked the participants whether they would request to extend their training duration for up to 6 months if given the right to do so. More than half of the participants (57.4%) had considered extending their residency training to overcome negative effects of the pandemic on their specialty training. Preference for an extension among neurosurgery residents should be a priority for program directors and other stakeholders to take necessary actions to mitigate negative and maximize positive impacts of the pandemic on future neurosurgeons. This situation, in turn, can lead to better preparation for future crises and challenges that our profession might face.

**CONCLUSIONS**

In this nationwide survey, we have shown the continuing impact of the COVID-19 pandemic on neurosurgery residents in Turkey. They have been at the forefront of the challenge of the pandemic and paid the price for it by having an infection rate as high as 37.9%. Direct involvement in COVID-19 medical care, reduced time in neurosurgical services, decreased case volumes, and inadequate institutional responsiveness to the pandemic have resulted in a significant negative impact on their training. Considering the ongoing impact of the COVID-19 pandemic, we believe that the results of this survey could aid neurosurgical program directors and other stakeholders to take necessary actions to mitigate negative and maximize positive impacts of the pandemic on future neurosurgeons. This situation, in turn, can lead to better preparation for future crises and challenges that our profession might face.

**CRediT AUTHORSHIP CONTRIBUTION STATEMENT**

Balkan Sahin: Conceptualization, Methodology, Investigation, Data curation, Writing - original draft, Visualization. Sahin Hanalioglu: Methodology, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Supervision.

**REFERENCES**

1. World Health Organization Coronavirus (COVID-19) Dashboard. [Available at: https://covid19.who.int/](https://covid19.who.int/). Accessed March 29, 2021.
2. Ozoner B, Gungor A, Hasanov T, Toktas ZO, Kilic T. Neurosurgical practice during coronavirus disease 2019 (COVID-19) pandemic. World Neurosurg. 2020;140:e195-207.
3. Tsermoulas G, Zisakis A, Flint G, Belli A. Challenges to Neurosurgery During the Coronavirus Disease 2019 (COVID-19) Pandemic. World Neurosurg. 2020;139:329-335.
4. Jansson M, Liao X, Rello J. Strengthening ICU health security for a coronavirus epidemic. Intensive Crit Care Nurs. 2020;57;101612.
5. McKee M, Stuckler D. If the world fails to protect the economy, COVID-19 will damage health not just now but also in the future. Nat Med. 2020;26;640-642.
6. Kogan M, Klein SE, Hannon CP, Nolte MT. Orthopaedic education during the COVID-19 pandemic. J Am Acad Orthop Surg. 2020;28;e435-e4364.
7. Nassar AH, Zern NK, McIntyre LK, et al. Emergency restructuring of a general surgery residency program during the coronavirus disease 2019 pandemic: the University of Washington experience. JAMA Surg. 2020;155:624.
8. Vargo E, Ali M, Henry F, et al. Cleveland Clinic Akron general urology residency program’s COVID-19 experience. Urology. 2020;140:1-3.
9. Alhaj AK, Al-Saadi T, Mohammad F, Alabhi S. Neurosurgeons’ perspective on COVID-19: knowledge, readiness, and impact of this pandemic. World Neurosurg. 2020;139:e848-e858.
10. Dash C, Venkataram T, Goyal N, et al. Neurosurgery training in India during the COVID-19 pandemic: straight from the horse’s mouth. Neurosurg Focus. 2020;49:e6.
11. Zois C, Raffa G, Somma T, et al. COVID-19 and neurosurgical training and education: an Italian perspective. Acta Neurochir (Wien). 2020;162:1789-1794.
12. Bray DP, Stricsek GP, Malcolm J, et al. Letter: maintaining neurosurgical resident education and safety during the COVID-19 pandemic. Neurosurg. 2020;87:E189-E191.
13. Harary M, Bergsneider M. Letter: Approaches to mitigate impact of COVID-19 pandemic on neurosurgery residency application cycle. Neurosurgery. 2020;87:E212-E213.
25. Barrett ES, Horton DB, Roy J, et al. Prevalence of COVID-19 on neurosurgery resident research training. J Neurosurg. 2020;132:11-15.

26. World Health Organization. Prevention, identification, and management of health worker infections in the context of COVID-19: interim guidance. World Health Organization. Available at: https://www.who.int/publications/i/item/2020-352825-Accessed March 28, 2021.

27. Iyengar KP, Ish P, Upadhyaya GK, Malhotra N, Vaisby R, Jain VK. COVID-19 and morality in doctors. Diabetes Metab Syndr. 2020;14:1743-1746.

28. Jean WC, Ironside NT, Sack KD, Felbaum DR, Syed HR. The impact of COVID-19 on neurosurgeons and the strategy for triaging non-emergent operations: a global neurosurgery study. Acta Neurochir (Wien). 2020;162:1229-1240.

29. Field NC, Pfanstiehl K, Paul AR, Daffino JC, Adamo MA, Boulos AS. Letter to the Editor: decrease in neurosurgical program volume during COVID-19: residency programs must adapt. World Neurosurg. 2020;141:566-567.

30. Cherseb EB, Esene IN, Mahmoud MR, et al. A continental survey on the impact of COVID-19 on neurological training in Africa. World Neurosurg. 2021;147:88-115.

31. Borsa S, Bertani G, Pluderer M, Locatelli M. Our darkest hours (being neurosurgeons during the COVID-19 war). Acta Neurochir (Wien). 2020;162:1227-1228.

32. Saad H, Alawi H, Oyesiku N, Barrow DL, Olson J. Sheltered neurosurgery during COVID-19: the Emory experience. World Neurosurg. 2020;144:e202-e209.

33. Pelargos PE, Chakraborty A, Zhao YD, Smith ZA, Dunn IF, Bauer AM. An evaluation of neurosurgical education and training during COVID-19 and the implications for orthopaedic neurosurgical education and training. A systematic review. J Neurosurg. 2021;134:228-246.

34. Cikla U, Sahin B, Hanalioğlu S, Ahmed AS, Niemann D, Eksakylu MK. A novel, low-cost, reusable, high-fidelity neurosurgical training simulator for cerebrovascular bypass surgery. J Neurosurg. 2019;130:1663-1671.

35. Ashry AH, Soffar HM, Alsawy MF. Neurosurgical education and training during COVID-19 pandemic: a North American survey. World Neurosurg. 2020;140:e390-e396.

36. Khalafallah AM, Jimenez AE, Lee RP, et al. Impact of COVID-19 on an academic neurosurgery department: the Johns Hopkins experience. World Neurosurg. 2020;139:e164-e177.

37. Khalafallah AM, Lam S, Gami A, et al. A national survey on the impact of the COVID-19 pandemic upon burnout and career satisfaction among neurosurgery residents. J Clin Neurosci. 2020;30:137-142.

38. Bulduk EB, Yilmaz C. An analysis of the on-call clinical experience of a junior neurosurgical resident. Neurourgery. 2019;85:290-297.

39. Ramos O, Mierke A, Kinett MJ, Wongsawat DM, Dandisa O. COVID-19 pandemic and the implications for orthopaedic neurosurgical education and training. Acta Neurochir (Wien). 2019;162:1663-1671.

40. Schillia A, Raffa G, Priola SM, et al. Neurosurgery on the web: an analysis of the web-visibility of the European Neurosurgical Societies [e-pub ahead of print]. J Neurosurg Sci. https://doi.org/10.23736/Sorge-39616.19.0457X; accessed February 4, 2019.