



Contents lists available at ScienceDirect

North American Spine Society Journal (NASSJ)

journal homepage: www.elsevier.com/locate/xnsj

Educational impact of early COVID-19 operating room restrictions on neurosurgery resident training in the United States: A multicenter study [☆]



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ARTICLE INFO

Keywords:

Coronavirus

COVID-19

Neurosurgery training

Residency

Multicenter

Case volume

ABSTRACT

Background: The coronavirus (COVID-19) pandemic has caused unprecedented suspensions of neurosurgical elective surgeries, a large proportion of which involve spine procedures. The goal of this study is to report granular data on the impact of early COVID-19 pandemic operating room restrictions upon neurosurgical case volume in academic institutions, with attention to its secondary impact upon neurosurgery resident training. This is the first multicenter quantitative study examining these early effects upon neurosurgery residents caseloads.

Methods: A retrospective review of neurosurgical caseloads among seven residency programs between March 2019 and April 2020 was conducted. Cases were grouped by ACGME Neurosurgery Case Categories, subspecialty, and urgency (elective vs. emergent). Residents caseloads were stratified into junior (PGY1-3) and senior (PGY4-7) levels. Descriptive statistics are reported for individual programs and pooled across institutions.

Results: When pooling across programs, the 2019 monthly mean (SD) case volume was 214 (123) cases compared to 217 (129) in January 2020, 210 (115) in February 2020, 157 (81), in March 2020 and 82 (39) cases April 2020. There was a 60% reduction in caseload between April 2019 (207 [101]) and April 2020 (82 [39]). Adult spine cases were impacted the most in the pooled analysis, with a 66% decrease in the mean number of cases between March 2020 and April 2020. Both junior and senior residents experienced a similar steady decrease in caseloads, with the largest decreases occurring between March and April 2020 (48% downtrend).

Conclusions: Results from our multicenter study reveal considerable decreases in caseloads in the neurosurgical specialty with elective adult spine cases experiencing the most severe decline. Both junior and senior neurosurgical residents experienced dramatic decreases in case volumes during this period. With the steep decline in elective spine cases, it is possible that fellowship directors may see a disproportionate increase in spine fellowships in the coming years. In the face of the emerging Delta and Omicron variants, programs should pay attention toward identifying institution-specific deficiencies and developing plans to mitigate the negative educational effects secondary to such caseloads reduction.

Abbreviations: ACGME, Accreditation Council for Graduate Medical Education; COVID-19, coronavirus disease of 2019; OR, operating room; PGY, postgraduate year.

[☆] Short Summary Sentence: In this multicenter study, we report considerable decreases in case volume trends in the neurosurgical specialty during early COVID-19 OR restrictions, with elective adult spine cases experiencing the most severe decline.

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<https://doi.org/10.1016/j.xnsj.2022.100104>

Received 22 January 2022; Received in revised form 14 February 2022; Accepted 14 February 2022

Available online 19 February 2022

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Introduction

The 2019 coronavirus disease (COVID-19) pandemic has dramatically transformed the landscape of healthcare delivery and patient-provider interactions across the world [1]. In particular, neurosurgery departments have faced changes in the mode of delivery of healthcare as well as in the quantity of offered patient care services. Studies estimate a 40-80% reduction in case volumes at the initial stages of the pandemic in 2020 compared to the same months the year prior [2-7]. Spine surgery in particular has seen nationwide suspensions of elective surgeries, with a significant proportion of patients continuing to experience delays in surgery, potentially prolonging their disability and pain. [8] Neurosurgical residency training programs also faced dramatic changes, with one study estimating a 58% reduction in overall resident case volume [9].

Multiple studies have reported the negative effects of the COVID-19 pandemic upon surgical resident training [10-12], but few have documented its impact in the neurosurgical field [2,9]. Residents play an indispensable role in the neurosurgical team, and therefore, the spread of COVID-19 infections within our relatively small workforce could be simply catastrophic. Consequently, programs throughout the United States underwent temporary restructuring of their respective services to both limit exposure as well as to maintain workflow in face of the urgent reallocation of hospital resources required to meet the demands of the pandemic. Adaptive measures included transitioning didactics to a virtual setting, minimizing in-person handoffs, converting in-person consultations to telemedicine, and increasing cadaveric dissections and surgical simulation sessions [2, 3].

The impact of these changes upon neurosurgery residents has been assessed qualitatively in the literature [13, 14]. Multiple studies have performed survey questionnaire analyses among neurosurgical residents, universally reporting that the vast majority of residents have felt negatively affected by these changes [9, 13-15]. Given the disproportionate impact of COVID-19 on neurosurgical departments across the country, quantitative multicenter data focused on residents training may allow clinicians and trainees to obtain a better understanding of its actual effects [4-6, 9, 16]. Currently, to our knowledge, there is only one previous multicenter analysis of neurosurgical procedural data in the United States [16]. However, the methodology employed was based on surveying resident experience and did not include the specific impact of surgical volume as stratified by Postgraduate year (PGY) level. Overall, the degree to which neurosurgical residency training has been influenced has mostly been reported in single-center studies [17, 18].

In this multicenter study, we provide granular data on the effects of early COVID-19 on neurosurgical case volumes as grouped by Accreditation Council for Graduate Medical Education (ACGME) Common Program Requirements and neurosurgical subspecialties. In addition, we report the first multicenter quantitative study examining the educational impact of such restrictions upon residents caseloads and discuss potential compensatory measures to alleviate the long-term impact of such deleterious effects. We hypothesized that neurosurgical residents would experience the steepest decreases in operative volume between March and April 2020, with elective spine cases experiencing greater declines compared to other neurosurgical subspecialties. In addition, we hypothesized a larger reduction in cases seen in junior-level residents compared to their senior counterparts. As uncertainties continue to arise with the advent of novel SARS-CoV-2 variants, these results are expected to provide insight to clinicians and program directors to better discern which aspects of residency training are most vulnerable to changes in healthcare delivery and to identify possible modifications to graduate medical education to ensure neurosurgical resident success.

Materials and methods

Study design

We conducted a retrospective review of de-identified neurosurgical case volumes and neurosurgery residents caseloads among seven large

tertiary care academic centers in the United States from March 2019 to April 2020. This study was designed and reported according to STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [19]. Centers included in this study span multiple geographic locations of the United States (Fig. 1): Houston Methodist Hospital, Saint Louis University Hospital, Yale New Haven Hospital, Ohio State Wexner Medical Center, University of Illinois at Peoria, SUNY Upstate University Hospital, and Penn State College of Medicine. This study was determined by the Saint Louis University Human Subjects Protection Program Office to not meet the Common Rule definition of human subjects' research, and as such, patient consent was not necessary.

Surgical procedures

The total caseloads for each institution were obtained from department records, based on the ACGME case log system reports provided by members of each individual institution participating in the study. Current Procedural Terminology (CPT) codes were used to characterize cases into four groups, according to ACGME Neurological Surgery Defined Case Categories: adult cranial, adult spinal, pediatrics, and other (Appendix T1).

Cases were also divided into neurosurgical subspecialty services: adult functional, adult tumor, adult vascular, adult trauma, adult spine, and pediatrics (Appendix T2). Residents caseloads per month were matched by each institution for comparison by PGY level. Combining adult and pediatric cases, surgeries were also grouped into elective or emergent cases. A case was considered elective if the patient was admitted on the day of a scheduled surgery. Cases were defined as emergent if the patient was admitted through the emergency department or clinic and underwent surgery during that hospital stay.

Descriptive analysis

Case volume data from March 2019 to April 2020 was included. Caseloads were grouped into the 2019 (March-December) and 2020 (January-April) monthly numbers. As each institution had differing state-regulated COVID-19 restrictions, cases were also stratified by month (e.g., March 2019, April 2020) for month-to-month trend comparisons. Data was pooled among the seven institutions, and resident training level was stratified into junior (PGY1 - PGY3) and senior (PGY4 - PGY7) level status. Pooled caseloads from all institutions were grouped by PGY resident level and divided by the total number of residents at the respective year (Appendix T3).

A descriptive analysis was chosen as the best method for reporting data because, given baseline differences in case variances among institutions and the heterogeneous residents population samples, the assumptions of parametric tests were not fulfilled in this study. In addition, matched comparisons of consecutive months between different years or within the same year among hospitals would be subject to the significant confounding effects of monthly seasonality. Categorical variables were reported as frequencies and percentages, and continuous variables were reported as the mean and standard deviation. All analyses were performed using the R statistical software, version 4.1.0.

Results

Among the seven institutions, a total of 88 ACGME resident case logs (42 juniors, 46 seniors) were reviewed. The number of residents from each institution are described in Appendix T3. The contributing institutions are large tertiary-care academic centers of different sizes, ranging from 1 to 3 residents enrolled per postgraduate year and including between 6-21 faculty members. The seven institutions were spread throughout different geographic locations in the United States (Fig. 1).

COVID-19 Case Rate in the US Reported to the CDC, by State/Territory (cases per 100,000)

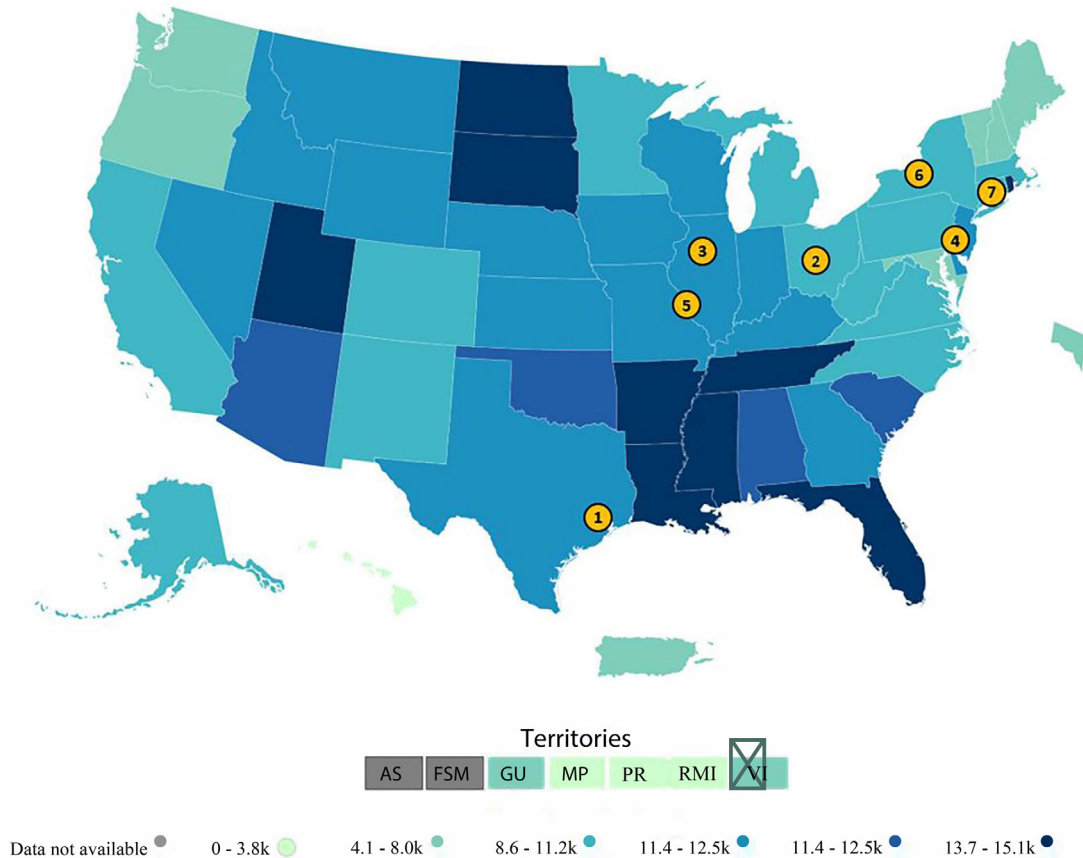


Fig. 1. Geographic locations of the seven represented neurosurgery residency programs. States are shaded according to the confirmed COVID-19 case rate per 100,000 individuals as reported to the CDC as of January 21, 2020. Programs included in this study are as follows: (1) Houston Methodist, (2) Ohio State University, (3) University of Illinois at Peoria, (4) Penn State College of Medicine, (5) Saint Louis University, (6) SUNY Upstate Medical University, (7) Yale University. (Adapted from the Centers for Disease Control and Prevention. CDC COVID Data Tracker. Available at: https://covid.cdc.gov/covid-data-tracker/#cases_casesper100k. Accessed August 23, 2021.) AS: American Samoa; FSM: Federated States of Micronesia; GU: Guam; MP: Northern Mariana Islands; PW: Puerto Rico; RMI: Republic of the Marshall Islands; VI: Virgin Islands

COVID-19 impact on institutional caseload

Pooled caseload results

In 2019, when pooling data from all seven institutions, there was a mean of 214 (SD: 123) cases per month, compared to 167 (SD: 107) cases per month for the first 4 months of 2020. Month-to-month trends in 2020 revealed a mean of 217 (SD: 129) cases in January, 210 (SD: 115) cases in February, 157 (SD: 81) cases in March, and 82 (SD: 39) cases in April 2020 (Fig. 2; Table 1). The largest caseload decrease was seen between March 2020 and April 2020 (48% downtrend). There were no differences in the case volume between March 2019 and March 2020, but in the pooled analysis we noticed a 60% downtrend between April 2019 (Mean [SD]: 207 [101]) and April 2020 (Mean [SD]: 82 [39]). When stratifying by institution, all academic sites experienced decreases in caseloads between March 2020 and April 2020 (Fig. 2). Houston Methodist Hospital experienced the largest decrease in the mean caseload (58%).

Grouping by ACGME case categories

When stratifying by ACGME Common Program Requirements, the largest decreases in the mean number of cases were seen between March 2020 and April 2020: adult cranial (31%), adult spine (67%), pediatrics (50%), and all other cases (36%) (Table 1). When stratifying by subspecialty service, all case types experienced decreases between February 2020 and March 2020 as well as between March 2020 and April 2020.

Adult spine cases were impacted the most in the pooled analysis with a 66% decrease in the mean number of cases between March 2020 and April 2020 (Fig. 3).

Elective vs. emergent cases

Between February 2020 and March 2020, elective cranial and elective spine cases decreased by 29% and 28%, respectively (Fig. 4). Between March 2020 and April 2020, the trend progressed to a 32% and 64% decrease in the mean number of cases, respectively (Fig. 4). When combining all elective cases regardless of subspecialty, there was a 60% decrease between April 2019 (Mean [SD]: 43 [36]) and April 2020 (Mean [SD]: 17 [15]). There was no difference in the trend of total elective cases between March 2019 and March 2020. As expected, emergent cases had a stable volume throughout the entire study period (March 2019 to April 2020) (Fig. 4).

Effects on resident training

A total of 88 resident case logs (42 juniors, 46 seniors, Appendix T3) were reviewed for the study period. All resident levels experienced a progressive decrease in mean monthly caseloads during the study period (Fig. 5a). When grouping by seniority, both junior and senior residents experienced a similar steady decrease in caseloads trends, with the largest decreases occurring between March 2020 to April 2020 (58% and 45% respectively) (Fig. 5b). When comparing April 2019 with April 2020, junior resident caseload means decreased by 55% compared to

Table 1
Pooled Mean Number of Cases per Month Stratified by Accreditation Council of Graduate Medical Education (ACGME) Requirements in 2019 vs. 2020

Case Type	2019 Monthly Mean (SD)	2020 Monthly Mean (SD)	January 2020 (SD)	February 2020 (SD)	March 2020 (SD)	April 2020 (SD)	
Adult	Tumor: General	21 (15)	18 (12)	24 (16)	22 (12)	15 (10)	12 (6)
Cranial	Tumor: Sellar/Parasellar	5 (5)	3 (5)	4 (6)	7 (7)	3 (3)	1 (2)
	Trauma/Infectious/Other	11 (5)	9 (5)	12 (5)	8 (4)	9 (4)	6 (4)
	Vascular: Open	4 (4)	4 (4)	5 (4)	4 (4)	5 (3)	4 (4)
	Vascular: Endovascular	36 (44)	30 (35)	39 (47)	41 (41)	25 (28)	18 (19)
	CSF Diversion/ETV/Other	10 (7)	8 (7)	11 (8)	10 (8)	7 (7)	5 (5)
	Pain	3 (3)	3 (4)	5 (5)	3 (3)	2 (2)	1 (1)
	Functional Disorder	4 (3)	2 (3)	4 (3)	3 (3)	1 (1)	0 (0)
	Epilepsy	2 (2)	1 (1)	1 (1)	2 (2)	1 (1)	0 (1)
	Emergent	9 (4)	8 (5)	10 (5)	7 (6)	8 (7)	7 (3)
	Elective	80 (77)	63 (60)	82 (83)	79 (74)	55 (44)	39 (27)
	Total	97 (67)	79 (57)	105 (72)	96 (65)	68 (44)	47 (27)
Adult Spinal	Anterior Cervical	15 (12)	12 (10)	15 (12)	17 (11)	13 (9)	5 (4)
	Posterior Cervical	9 (7)	7 (6)	9 (7)	8 (8)	8 (6)	2 (2)
	Thoracic/Lumbar/Sacral/Instrumentation/Fusion	23 (15)	16 (13)	19 (14)	21 (13)	17 (15)	6 (5)
	Lumbar Laminectomy/Laminotomy	25 (30)	17 (22)	23 (29)	23 (28)	16 (19)	7 (7)
	Stimulation/Lesion/Pump/Other	11 (12)	9 (10)	12 (11)	12 (13)	9 (11)	2 (2)
	Emergent	3 (3)	2 (2)	2 (2)	2 (2)	2 (1)	1 (2)
	Elective	64 (73)	46 (57)	59 (75)	63 (70)	46 (53)	17 (15)
	Total	84 (67)	62 (56)	80 (65)	83 (62)	63 (52)	21 (18)
Adult Other	Peripheral Nerve	4 (4)	3 (3)	4 (3)	5 (4)	2 (3)	1 (1)
	Radiosurgery	3 (5)	3 (6)	5 (8)	4 (6)	3 (5)	3 (4)
	Peripheral Device Management	9 (9)	7 (5)	10 (6)	6 (4)	7 (5)	4 (4)
	Emergent	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Elective	8 (6)	7 (6)	10 (7)	8 (5)	7 (6)	4 (5)
	Total	15 (14)	12 (11)	17 (14)	14 (12)	11 (9)	7 (7)
Pediatric	Cranial: Tumor	2 (2)	2 (2)	3 (2)	3 (2)	2 (2)	1 (1)
	Cranial: Trauma/Other	5 (4)	4 (3)	4 (2)	5 (6)	5 (2)	2 (2)
	CSF Diversion/ETV/Other	10 (9)	8 (5)	8 (5)	11 (8)	7 (4)	5 (3)
	Spinal	2 (2)	2 (2)	3 (1)	3 (2)	3 (2)	1 (1)
	Emergent	2 (2)	2 (1)	1 (1)	2 (2)	2 (1)	2 (2)
	Elective	18 (15)	14 (12)	14 (11)	20 (18)	14 (8)	7 (6)
	Total	20 (14)	16 (10)	17 (8)	21 (16)	18 (5)	9 (5)
All Case Types		214 (123)	167 (107)	217 (129)	210 (115)	157 (81)	82 (39)

Cases per Month Stratified by Institution

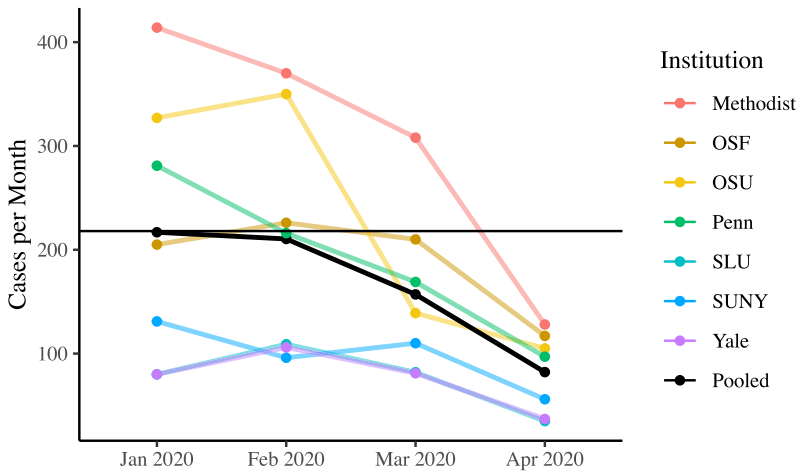


Fig. 2. Mean cases per month stratified by institution in 2019 and 2020. The horizontal black line represents the 2019 mean monthly average (219 cases per month). All universities experienced decreases in caseloads between March and April 2020. Houston Methodist University experienced the largest decrease in the mean caseload (March/April 2020: 58%). The SLU and Yale caseloads were very similar, with differences in the single-digits at each period to the point that curves seem to overlap in the above depiction.

Cases per Month Stratified by Subspecialty

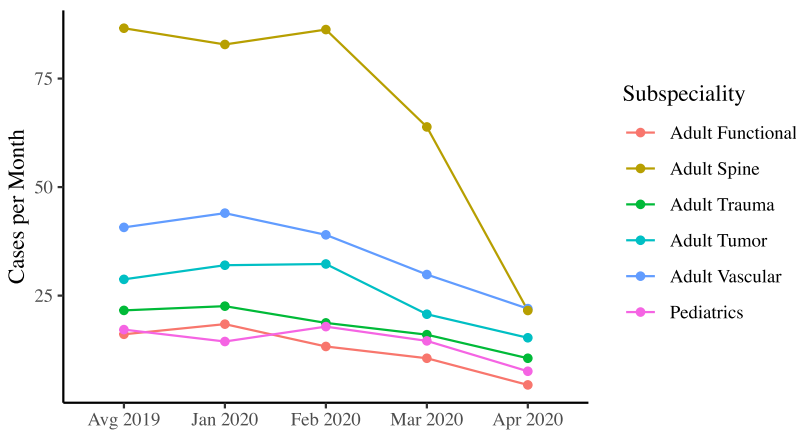


Fig. 3. Pooled mean cases per month of seven neurosurgery residency programs in 2019 and 2020, stratified by neurosurgical subspecialty services. All subspecialty services experienced a decreasing trend between February, March, and April 2020. Adult spine cases experienced by far the most severe decline (66% decrease between March 2020 and April 2020).

45% in senior residents. There was no difference in trends between March 2019 and March 2020 when comparing junior and senior residents.

Discussion

The COVID-19 pandemic has had an indiscriminate impact on virtually every aspect of healthcare around the world. In the surgical subspecialties, programs have undergone a universal effort to implement social distancing and methods to increase the safe delivery of healthcare services [5, 20]. Residency training programs have been significantly impacted, posing a need for the creation of alternative educational opportunities [3].

Impact on operative volume

The overall findings from our descriptive analysis pooled from seven academic institutions across the United States were consistent with previous reports in the literature [3, 5, 9, 16, 21]. Similar to Aljuboori et al., our results revealed a decrease when comparing the 2019 monthly mean to the monthly mean of the first four months in 2020. However, whereas Aljuboori and colleagues reported significant decreases in operative volume between January and February of 2020, our study showed a caseload decrease between February, March, and April 2020, with the largest downtrend between March and April (48%). Similarly, we also report that larger institutions, such as Houston Methodist University in our cohort, experienced steeper declines (Fig. 2) [16].

Caution should be taken when interpreting multicenter data in the setting of the coronavirus pandemic. Variances in state legislation, institutional policy, population density, rate of exposure, institutional baseline caseload, and monthly case seasonality among hospitals may limit the generalizability of such results [9, 16]. However, in all the seven institutions included in our study, public health emergencies and city shutdowns were mandated in a relatively narrow timeframe (early/mid-March, range 3/9/20 – 3/18/20; Appendix T4) [16]. This would explain why the majority of our results exhibited the steepest declines between March 2020 and April 2020, as compared with findings from other studies [9, 16]. State and institutional restrictions were broad in scope and effectively ceased all elective cases across all departments [22]. Given the disproportionate number of elective cases in the neurosurgical spine subspecialty, it is no surprise that elective adult spine cases experienced the most severe decreases during these early COVID-19 OR restrictions (Fig. 3, Fig. 4; Table 1) [9, 23]. The effect of such decreases may carry significant implications, as recent studies have reported significant delays in spine treatment that may prolong pain and disability in this patient population.[8]

Impact on neurosurgical resident training

There is a paucity of objective assessments on the impact of neurosurgical training during the coronavirus pandemic [9, 13, 16]. Few studies have documented single-center effects on residents case volume [9, 13], but to the authors' knowledge, no study has reported multicentered

Cases per Month Stratified by Elective vs. Emergent Surgery

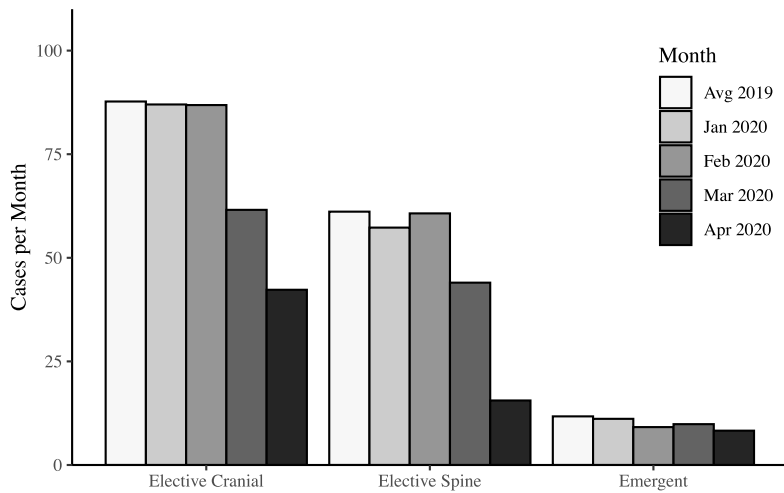


Fig. 4. Pooled mean number of elective cranial, elective spine, and emergent cases per month of seven neurosurgery residency programs in 2019 and 2020. Both elective cranial and elective spine experienced declines in mean number of cases between February, March, and April 2020. Emergent cases demonstrated a stable case volume throughout the entire study period (March 2019 to April 2020)

Pooled Cases per Month Stratified by Resident Year

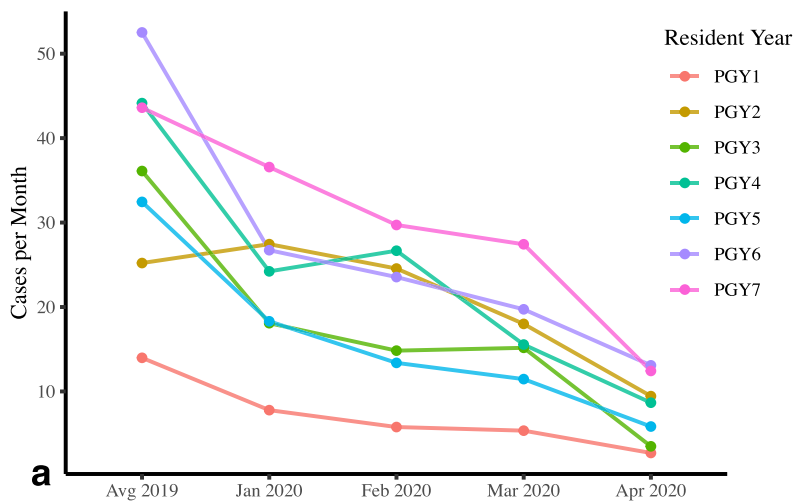
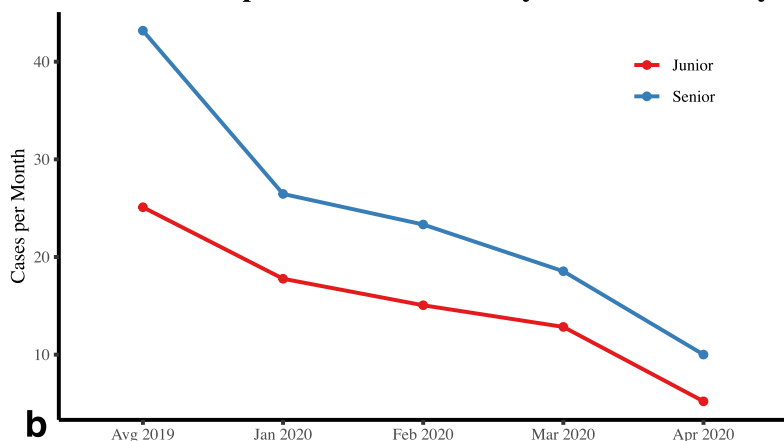


Fig. 5. Effects of COVID-19 on neurosurgical resident caseloads. A total of 88 ACGME resident case logs were included. (A) All resident levels experienced a progressive decrease in mean monthly caseloads during the study period (March 2019 to April 2020). (B) When grouping by seniority, both junior and senior residents experienced a steady decrease in caseloads, with the largest decreases occurring between March 2020 to April 2020 (58% and 45% respectively).

Pooled Cases per Month Stratified by Resident Seniority



data regarding the effect of early COVID-19 OR restrictions on residents caseloads as stratified by PGY level. Objective measurements regarding the differing effects on neurosurgical resident training may provide program directors with some guidance on how to further manage resident education moving forward [9, 16].

As state and institutional mandates were implemented in early/mid-March, programs likely started experiencing the effects of decreased operative volume by early April. Our study reflected these effects, with the steepest observed decline in case volumes occurring between March and April 2020 (Fig 5a). During these months, senior residents, especially chief residents, were gearing up towards fellowship or attending-level positions, and therefore, priority from remaining cases were likely deferred to senior residents. In addition, senior-level residents generally operate on the majority of life-threatening and emergent cases whereas junior residents tend to perform a larger percentage of routine elective cases (such as elective spine). As emergent cases remained stable whereas elective cases—specifically spine—experienced steep declines (Fig. 3, Fig. 4), junior residents lost access to routine elective procedures that serve as the bulk of their operative volume. For these reasons, we hypothesized that the effects of the COVID pandemic on operative volumes would be more pronounced in junior residents. Therefore, it was somewhat unexpected that the observed decrease was comparable between both resident populations (March and April 2020 [Junior: 58% decrease vs. Senior: 45% decrease] and April 2019 and April 2020 [Junior: 55% decrease vs. Senior: 45% decrease]).

Though the coronavirus pandemic has had deleterious effects on the surgical experience of junior and senior residents alike, studies have anecdotally and qualitatively documented compensatory measures to supplement resident training. One approach that programs have utilized in order to enhance residency training has been an increase in research activities that can be performed remotely [16]. Although residents were initially unable to physically conduct lab benchwork [18], programs have shifted towards increasing the amount of bioinformatics, large database (such as the American College of Surgeons National Surgical Quality Improvement Program - ACS/NSQIP), or chart-based projects and working with residents to sharpen scientific writing and grant applications. Indeed Aljuboori et al. documented that the majority of programs included in their multicenter study (87.5%) have seen an increase in research productivity in early 2020 [16].

In addition to increased opportunity for clinical research, programs have universally documented the use of virtual conferences and didactic sessions to supplement resident education [14]. Although virtual sessions may detract from the intimate mentor-mentee experience, they have provided an inexpensive way to invite guest lecturers to teach and interact with the resident body. Along similar lines, at the medical student level, transition to virtual interviews have afforded candidates the ability to explore far more programs than before, an experience that may have previously been limited by travelling or financial constraints.

Findings in context

There is no doubt that the COVID-19 pandemic has negatively affected the operative experience of neurosurgical residents, the long-term consequences of which remain largely unknown. In our cohort, when comparing respective months in 2019 to 2020, as well as months within 2020, both junior and senior residents experienced large decreases in their operative case volumes. Although the decreases were similar, the effects of such reductions may be substantially more daunting for senior residents, as they not only have less time to gain experience but may have missed out on complex elective cases which are the bedrock of senior resident level education.

Therefore, as other studies have suggested, one may see an increase in the number of residents pursuing subspecialty fellowship training in the near future [21]. Specifically, fellowship directors may see a disproportionate increase in spine fellowships, as our results, among others, revealed severe declines in adult spine caseloads. Another possible, but

likely very controversial measure, to address these problems would be for the ACGME to allow residents to extend their residency training for several months up to one year, although the complexity of this process would likely be a major limiting factor. So far, the ACGME has not provided any specific accommodation regarding the required case volume for resident graduation, having only emphasized that "It is up to the program director, with consideration of the recommendations of the program's Clinical Competence Committee, to assess the competence of an individual resident/fellow".

(<https://acgme.org/Newsroom/Newsroom-Details/ArticleID/10111/ACGME-Response-to-the-Coronavirus-COVID-19/>)

Other methods discussed in the literature to combat the negative effect of COVID-19 on neurosurgical residency training include the implementation of surgical courses, regular didactics via live video, and surgical simulators [9, 21]. Surgical simulators may serve as an excellent adjunct to resident education, particularly for refining manual or microsurgical skills [24–26]; however, due to the general high cost of virtual-based simulation systems and the required time to develop prototypes for synthetic simulation, it is unlikely that it would play a substantial role in the short-term efforts to mitigate the COVID pandemic impact on residents training. Alternatively, cadaveric operations in an anatomy lab led by attending level physicians may serve as an interesting surrogate to simulate, to a certain level at least, a live operative experience. The increased use of cadaveric operations, which is widely available at most programs, may indeed be a cost-effective way to continue skill progression at all levels of resident education [9, 16].

Our results demonstrate the widespread effects of complete lockdown and OR closure on the neurosurgical resident educational experience, with >60% drop in case volume from the 2019 average (214 cases) to the April 2020 average (82 cases) in our multicenter study. Although programs are slowly starting to return to pre-pandemic operative volumes, the emergence of potentially more severe coronavirus strains, such as the Delta and Omicron variants, remains a continuous threat to patients and providers alike. In addition, the possibility of the coronavirus becoming an endemic disease remains a serious consideration. Indeed, recent studies have commented on the endemic nature of SARS-CoV-2, with its severity, transmissibility, and reinfection rate remaining largely unknown [27–32].

Recently, a new SARS-CoV-2 variant of concern, Omicron, has emerged in a COVID-19-weary world and has already spread rapidly throughout the globe.[33, 34] In the face of these many uncertainties, both domestically and overseas, programs need to re-evaluate their prior strategies and equip themselves with initiatives to supplement resident education. This often requires innovation and creativity, as both physical limitations and financial restraints may prevent the implementation of traditional educational methods. The variability in our results suggest that a more individualized approach, tailored to institution and resident year, would be preferable. Time should be spent determining specific case types and resident years that were disproportionately affected, and action plans should be created to focus on areas of deficiency. In addition, the integration of sustainable, long-lasting initiatives to supplement resident education will serve as an indispensable tool to ensure high-quality training if reemerging disease necessitates repeat city shutdowns and OR closures. As the neurosurgical community moves forward together into unknown territory, residency programs must prepare themselves for a wide range of possible future scenarios

Limitations

Variances in state legislation, institutional policy, population density, rate of exposure, institutional baseline caseload, and monthly case seasonality among hospitals limit the extraction of more generalizable results from this data. Not only was the assumption of homogeneity of variance violated due to the pooling of seven institutions, but the baseline monthly seasonality of caseloads among institutions would not be

Table 2
2020 Monthly Percent Change in Resident Case Volume

PGY Year		2020 Monthly Percent Change		
		Jan-Feb	Feb-Mar	Mar-Apr
Junior	PGY-1	-26%	-7%	-49%
	PGY-2	-11%	-27%	-48%
	PGY-3	-18%	+2%	-77%
	Total	-18%	-11%	-58%
Senior	PGY-4	+10%	-42%	-44%
	PGY-5	-27%	-14%	-49%
	PGY-6	-12%	-16%	-34%
	PGY-7	-19%	-8%	-55%
Total		-12%	-20%	-45%

adequately controlled with parametric analyses. In addition, the self-selection process and small number of participating institutions may further introduce other types of biases and idiosyncrasies. Along these lines, data may not be representative of the experience of all U.S. neurosurgical residency programs, particularly because certain specific geographic locations (i.e., West Coast) were not included in this study. In addition, although we report that city shutdowns in our cohort occurred in a similar time range (3/9/20-3/18/20), the actual implementation and downstream effects on hospitals differ. Another important limitation is the lack of long-term follow up and analysis of the case volume trend in subsequent months. Although a recent study revealed that earlier months in 2020 were more affected, a complete assessment of 2020 would be significantly more conducive to fully assessing the effects of the COVID pandemic as well as the rate of rebound in surgical cases [9]. Despite the multiple limitations, however, this is the first study to use multicentered data to quantitatively assess the impact of the COVID pandemic on neurosurgical residency training. We hope these findings can help inform future decision-making with respect to the training of future neurosurgeons.

Conclusion

The COVID-19 pandemic has had an unprecedented impact on virtually all aspects of healthcare around the world. The results from this multicentered study demonstrate considerable decreases in case volumes in the neurosurgical specialty, with elective adult spine cases experiencing the most severe declines. Both junior and senior level neurosurgical residents experienced progressive, yet dramatic and similar decreases in their operative case volumes during the early COVID-19 OR restrictions. Specifically, the steep decline observed in elective spine cases may spark an increase in spine fellowships in the coming years. In the face of the current effects of the Delta and Omicron variants, neurosurgery residency programs should identify institution-specific deficiencies, and develop long-term plans to mitigate the unanticipated deleterious effects of this global pandemic on the quality of resident training (Table 2).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

None

Statements & declarations

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript. In addition, the authors have no relevant financial or non-financial interests to disclose. This is a retrospective observational study. The Saint Louis University

Research Ethics Committee has confirmed that no ethical approval is required.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2022.100104.

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