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## Early Effects of COVID-19 Pandemic on Neurosurgical Training in the United States: A Case Volume Analysis of 8 Programs

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■ **OBJECTIVE:** To determine the impact of the 2019 novel coronavirus disease (COVID-19) pandemic on operative case volume in 8 U.S. neurosurgical residency training programs in early 2020 and to survey these programs regarding training activities during this period.

■ **METHODS:** A retrospective review was conducted of monthly operative case volumes and types for 8 residency programs for 2019 and January through April 2020. Cases were grouped as elective cranial, elective spine, and nonelective emergent cases. Programs were surveyed regarding residents' perceptions of the impact of COVID-19 on surgical training, didactics, and research participation. Data were analyzed for individual programs and pooled across programs.

■ **RESULTS:** Across programs, the 2019 monthly mean  $\pm$  SD case volume was  $211 \pm 82$ ; 2020 mean  $\pm$  SD case volumes for January, February, March, and April were  $228 \pm 93$ ,  $214 \pm 84$ ,  $180 \pm 73$ , and  $107 \pm 45$ . Compared with 2019, March and April 2020 mean cases declined 15% ( $P = 0.003$ ) and 49% ( $P = 0.002$ ), respectively. COVID-19 affected surgical case volume for all programs; 75% reported didactics negatively affected, and 90% reported COVID-19 resulted in increased research time. Several neurosurgery residents required COVID-19 testing; however, to our knowledge, only 1 resident from the participating programs tested positive.

■ **CONCLUSIONS:** This study documents a significant reduction in operative volume in 8 neurosurgery residency training programs in early 2020. During this time, neurosurgery residents engaged in online didactics and research-related activities, reporting increased research productivity. Residency programs should collect data to determine the educational impact of the COVID-19 pandemic on residents' operative case volumes, identify deficiencies, and develop plans to mitigate any effects.

### INTRODUCTION

The first case of 2019 novel coronavirus disease (COVID-19) in the United States was reported in Seattle, Washington, on January 20, 2020, and the first mortality was reported on February 26, 2020.<sup>1</sup> Originating from Wuhan, China, in late 2019, the causative virus of COVID-19, severe acute respiratory syndrome coronavirus 2, has spread rapidly across the globe. The World Health Organization declared COVID-19 a global pandemic on March 11, 2020,<sup>2</sup> and at the time of this writing,  $>7$  million people in the United States have been infected, resulting in  $>200,000$  deaths.<sup>3</sup> To slow the spread of the infection, U.S. state authorities independently implemented various social distancing measures. Under advisory from health authorities, hospital systems around the nation took aggressive steps to prepare for an influx of critically ill patients, including the

#### Key words

- Case volume
- Coronavirus
- COVID-19
- Neurosurgery training
- Residency
- Skills

#### Abbreviations and Acronyms

**ABNS:** American Board of Neurological Surgery

**ACGME:** Accreditation Council for Graduate Medical Education

**COVID-19:** 2019 novel coronavirus disease

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cancellation and postponement of nonurgent elective surgical procedures.<sup>4</sup> This reduction in surgical case volume raised the potential for a corresponding negative impact on neurosurgical training programs. The COVID-19 pandemic presents a unique challenge compared with prior natural disasters or administrative upheavals in which only one or a few residency programs were affected. To quantify the impact of the COVID-19 pandemic on neurosurgical residency training, we compared the operative case volumes in 8 U.S. training programs in January through April 2020 with 2019 operative case volumes at these same institutions. In addition, each program was surveyed regarding residency program training activities in January through April 2020 compared with 2019 training activities.

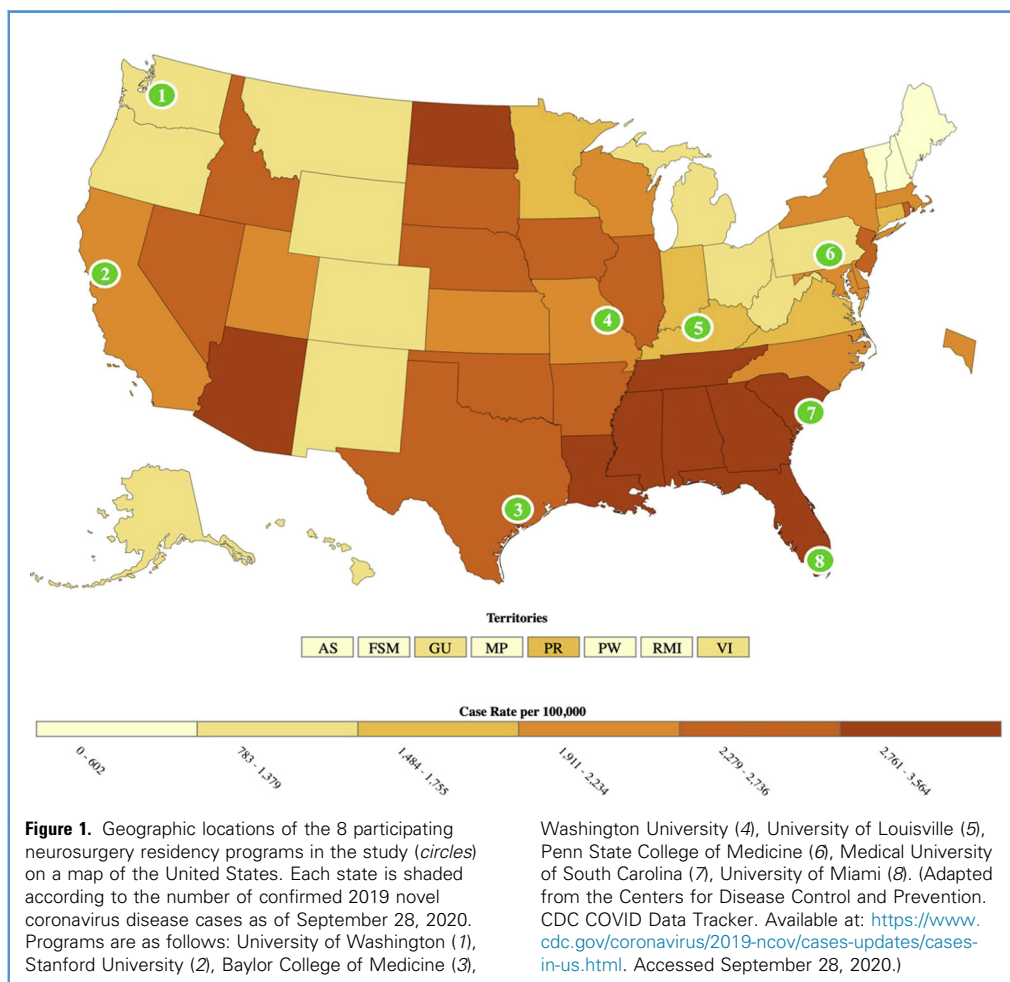
## MATERIALS AND METHODS

This retrospective review of de-identified operative case volume data (excluding endovascular cases) and survey responses was reviewed by the University of Louisville Human Subjects Protection Program Office and determined to not meet the Common Rule definition of human subjects research. Programs were selected based on willingness to provide data for the study, identification

of a lead resident to provide survey responses, and geographical location. Specifically, U.S. residency programs located in different geographical regions across the United States were approached for participation.

After obtaining operative case volume data from each institution's data repository, surgeries were grouped into 3 categories: 1) elective cranial, 2) elective spine, and 3) emergent/non-elective. A case was considered elective when the patient was admitted to the hospital on the day of the scheduled surgery. A case was considered emergent when the patient was admitted through the emergency department or clinic and underwent an unplanned surgery.

A study-specific questionnaire was developed to assess potential effects of the COVID-19 pandemic on research, didactic, and clinical aspects of residency program activities. Survey questions included effects on frequency and presentation of didactics, case volumes, time available for research and research activities, and supplementary activities to surgical training. Survey questions included both "yes/no" and "better/worse/same" response options as applicable. A lead resident from each participating program was identified to respond to the survey.



**Table 1.** Pairwise Comparison of Monthly Mean Operative Case Volume

Time Period	Case Number, Mean $\pm$ SD	Time Period			
		2019 Monthly Mean	January 2020	February 2020	March 2020
		211 $\pm$ 82	228 $\pm$ 93	214 $\pm$ 84	180 $\pm$ 73
January 2020	228 $\pm$ 93	$P = 0.05$			
February 2020	214 $\pm$ 84	$P = 0.05$	$P = 0.02$		
March 2020	180 $\pm$ 73	$P = 0.003$	$P = 0.001$	$P = 0.001$	
April 2020	107 $\pm$ 45	$P = 0.002$	$P = 0.002$	$P = 0.002$	$P = 0.01$

Descriptive statistics were calculated as percentages, means, and SD. Paired t test was used to perform a pairwise comparison of the means. The significance level was assessed at  $P < 0.05$ . Statistical analysis was conducted with STATA 13 (StataCorp LLC, College Station, Texas, USA).

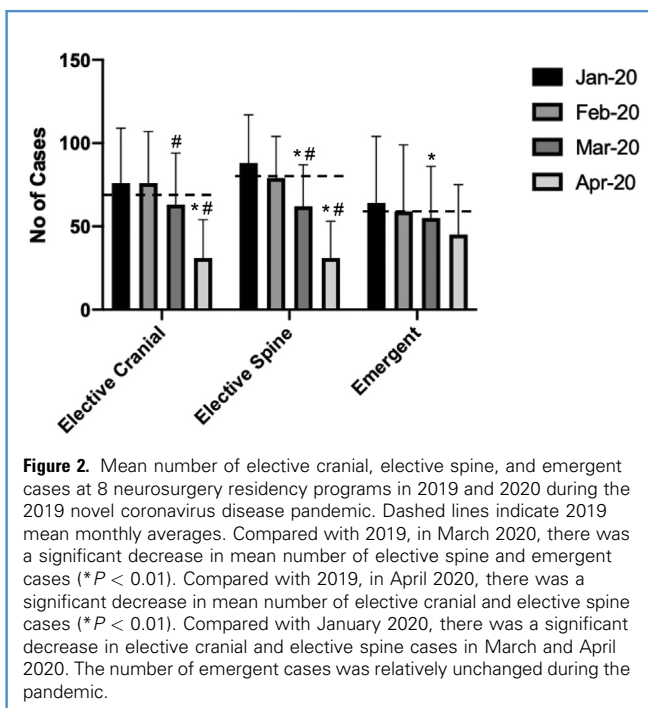
## RESULTS

Eight U.S. residency programs participated in this study; locations of programs are shown in **Figure 1**. The surveyed programs were university programs of assorted sizes ranging from 2 to 4 residents enrolled at each postgraduate year and including 10–60 faculty members. All programs provided case volume data for 2019 and for January through April 2020. For 2019, all programs combined reported a mean of  $211 \pm 82$  operative cases per month. For the first 4 months of 2020, the mean monthly operative case volume across all programs was  $182 \pm 70$ . There was a trend toward increases in mean operative volume for January 2020 ( $228 \pm 93$ ) and February 2020 ( $214 \pm 84$ ) compared with the 2019 mean monthly operative volume across all programs; however, these increases were not significant. Programs experienced significant decreases in mean operative case volume in March 2020 ( $180 \pm 73$ ) and April 2020 ( $107 \pm 45$ ) compared with the 2019 mean operative case volumes (15%,  $P = 0.003$  and 49%,  $P = 0.002$ , respectively) (**Table 1**). Compared with January 2020, there was a significant reduction in operative cases in February 2020, March 2020, and April 2020 (6%,  $P = 0.02$ ; 21%,  $P = 0.001$ ; and 53%,  $P = 0.002$ , respectively).

For 2019, the mean monthly operative case volume across all programs included 33% elective cranial ( $70 \pm 29$ ), 37% elective spine ( $78 \pm 31$ ), and 29% nonelective procedures ( $61 \pm 32$ ) (**Figure 2**). For the first 4 months in 2020, the mean monthly operative case volume across all programs included 34% elective cranial, 36% elective spine, and 31% nonelective procedures. Compared with 2019, in March 2020 there were significant decreases in case volume across all institutions for elective spine and nonelective/emergent cases (21%,  $P = 0.002$ , and 9%,  $P = 0.01$ , respectively), but not for elective cranial surgeries (11%,  $P = 0.2$ ). Compared with 2019, April 2020 showed a significant decrease in 2 surgical categories (elective cranial, 56%,  $P = 0.003$ , and elective spine, 61%,  $P = 0.002$ ), with no significant decrease for nonelective/emergent cases (26%,  $P = 0.1$ ). Compared with January 2020, March 2020 showed a significant decrease in elective surgical categories (elective

cranial, 17%,  $P = 0.008$ , and elective spine, 30%,  $P = 0.001$ ). In addition, April 2020 showed a significant decrease in elective surgical categories (elective cranial, 59%,  $P = 0.003$ , and elective spine, 65%,  $P < 0.0001$ ). When examining individual programs, compared with 2019, by March 2020 all individual programs demonstrated declines in operative volume compared with the 2019 monthly mean (**Table 2**); however, some reported declines in case volume in January 2020 (University of Louisville) and February 2020 (University of Louisville, University of Miami, Penn State College of Medicine, Medical University of South Carolina).

All programs responded to the survey; survey questions and responses are shown in **Table 3**. Consistent with the operative case data, all respondents reported a decrease in surgical case volume during the COVID-19 pandemic; 37.5% thought this would have a negative impact on their surgical skills, whereas 62.5% did not think the decrease in case volume would negatively affect surgical skill acquisition. Of respondents, 75% stated that the COVID-19



**Table 2.** Change in Operative Case Volume for Each Residency Training Program by Month for January Through April 2020 Compared with 2019 Monthly Mean as a Reference

Program	State	2019 Monthly Mean	Monthly Case Numbers and Percent Change from 2019 Monthly Mean for Each Program			
			January 2020	February 2020	March 2020	April 2020
University of Louisville	Kentucky	99	97 (−2%)	86 (−13%)	71 (−28%)	68 (−31%)
University of Washington	Washington	229	267 (+17%)	248 (+8%)	196 (−14%)	147 (−36%)
University of Miami	Florida	346	368 (+6%)	340 (−2%)	313 (−10%)	132 (−62%)
Baylor College of Medicine	Texas	125	132 (+6%)	138 (+11%)	122 (−2%)	31 (−75%)
Penn State College of Medicine	Pennsylvania	151	169 (+12%)	149 (−1%)	142 (−6%)	80 (−47%)
Washington University St. Louis	Missouri	273	323 (+18%)	290 (+6%)	234 (−14%)	97 (−64%)
Stanford University	California	213	232 (+9%)	230 (+8%)	179 (−16%)	157 (−26%)
Medical University of South Carolina	South Carolina	249	234 (−6%)	230 (−8%)	182 (−27%)	144 (−42%)
Total number of cases		1685	1822	1711	1439	856

pandemic had negatively affected didactics at their programs. All respondents indicated their programs were providing didactics online, with 87.5% of respondents indicating their programs were providing only online didactics, and 12.5% indicating that both in-person and online didactics were provided. No programs provided in-person didactics only, and no programs canceled didactic learning activities. Of respondents, 50% reported that the online format was better than in person, 12.5% thought it was similar, and 37.5% thought the online didactics provided were worse than in-person training. In addition, respondents reported increased engagement with residency research activities, with 87.5% reporting that the COVID-19 pandemic resulted in more time for research and 62.5% reporting an increase in the number of articles, abstracts, or chapters written, submitted, or published during this time. Between January and April 2020, telemedicine was used to provide neurosurgical consultation in 50% of the programs surveyed, with 12.5% of respondents reporting frequent telemedicine usage and 37.5% reporting infrequent usage. No residents in the participating programs were re-deployed to provide non-neurosurgical clinical care. Of respondents, 75% reported their programs tested neurosurgery residents for severe acute respiratory syndrome coronavirus 2; 1 resident from the participating programs tested positive during the study time period (Table 3).

## DISCUSSION

In the United States, neurological surgery residents and neurological surgery training programs are under the oversight of the Accreditation Council for Graduate Medical Education (ACGME) and the American Board of Neurological Surgery (ABNS). The stated mission of the ACGME is “to improve health care and population health by assessing and advancing the quality of resident physicians’ education through accreditation.”<sup>5</sup> The ACGME provides accreditation for neurological surgery residency training programs. The primary purposes of the ABNS are to set training standards and conduct examinations of candidates who seek

board certification. The ABNS, along with the Residency Review Committee for Neurological Surgery of the ACGME, works to improve the standards of training of residents in neurosurgical residency programs throughout the United States.

While there is variation in resident experience among the 112 accredited programs, training is highly structured with pre-defined length (84 months), metrics for 6 ACGME core competencies, and a minimum number of surgical cases (800) required for graduation.<sup>6</sup> The COVID-19 pandemic elicited far-reaching responses from health authorities, leading to a sudden and significant reduction in elective operative volume in neurosurgery as shown by our data and reported by others.<sup>4,7-9</sup> The decline in operative volume identified in our analysis affected all responding residency programs regardless of their geographical location. Programs were affected at distinct time points across the 4-month study time period, perhaps related to differences in institutional policies, differences in individual state or local directives, and unpredictable patterns of the viral spread. The subgroup analysis, which showed the decline had affected only the elective cases, supported this hypothesis. In many hospitals, clinical needs related to the COVID-19 pandemic required restructuring of clinical services and re-deployment of residents and staff outside of their subspecialty departments<sup>10-12</sup>; however, that was not the case for any of our neurosurgery program respondents.

Interpreting these data is challenging given the definition of an urgent versus nonurgent elective case is often indistinct and subject to interpretation.<sup>13</sup> In our study, cases were identified as elective or emergent retrospectively. The elective subset was chosen when admission was on the day of a prior scheduled surgery. The term “emergent” was selected when admission was through the emergency department or was an unplanned surgery immediately following a clinic visit. A commonly used criterion for a nonurgent elective procedure is an operation that, if postponed for 3 months, would not result in significant harm to the patient. In contrast, neurosurgical cases are often

**Table 3.** Survey Questions and Responses from 8 Neurological Surgery Residency Training Programs

Question	Response, %
Did COVID-19 negatively affect didactics in your program?	
Yes	75
No	25
Residents' didactics during COVID-19?	
Online only	87.5
Online and in person	12.5
In person only	0
Cancelled	0
Learning through virtual didactics compared with in person?	
Better	50
Worse	37.5
Same	12.5
N/A	0
Which of the following methods are used by your program to supplement operative training during COVID-19?	
Self-directed learning	100
Virtual didactics by webinar	100
Cadaveric dissection	0
Surgical simulation	0
Did COVID-19 negatively affect surgical case volume at your program?	
Yes	100
No	0
Do you think that COVID-19 will negatively impact your surgical skills?	
Yes	37.5
No	62.5
Has COVID-19 affected research activities at your program?	
Yes	100
Better	37.5
Worse	25
No	0
How has COVID-19 impacted time available for research activities?	
More time	87.5
Less time	12.5
Same	0
How has COVID-19 affected number of articles/abstracts/chapters written/submitted/published?	
Increased	62.5
Continues	

**Table 3.** Continued

Question	Response, %
Decreased	0
No change	37.5
Have residents in your program used telemedicine to perform formal neurosurgery consultation during COVID-19?	
No	50
Yes, occasionally	37.5
Yes, frequently	12.5
Are any of your residents re-deployed to provide non-neurosurgery clinical care?	
Yes	0
No	100
Has any resident required testing for COVID-19?	
Yes	75
No	25
Number of residents positive	1
COVID-19, 2019 novel coronavirus disease; N/A, not applicable.	

considered urgent if there is a concern for progressive neurological deficits, oncologic progression, or persistent and severe symptoms.<sup>10,11</sup>

Regardless of the specific category, decreases in operative volume persisted when hospitals limited elective procedures in response to the COVID-19 pandemic. Strategies aimed at mitigating the negative effects of the COVID-19 pandemic on residents' training have been both flexible and creative to address local policies regarding institutional resources and the COVID-19 case burden. The availability of high-fidelity surgical simulators may serve as a supplement to operative training, as others have noted.<sup>14</sup> Also, neurological surgery residents have recently reported developing a home microsurgery laboratory in direct response to the need to continue surgical skill acquisition during the COVID-19 pandemic.<sup>15</sup>

It will be important for each residency program to collect data to determine the effect of the COVID-19 pandemic on resident case types and volumes. Each program could assess their data and develop action plans to identify any deficiencies identified. For example, restructuring residents' rotations to ensure adequate exposure to certain case types may be beneficial. Also, establishing simulation and microanastomosis stations where the residents can practice improving their surgical skills may be helpful.

The full extent of the impact of the decline in operative volume associated with the COVID-19 pandemic on resident education is difficult to predict for many reasons, including the variability of the viral spread. For example, Texas has recently experienced a significant increase in the number of cases of COVID-19, and among other responses, the state government ordered hospitals to cancel and postpone all elective surgeries as of June 25, 2020.<sup>16</sup>

Furthermore, impact on individual residents may vary greatly, depending on resident training level, affected rotations, program location, program operative volume, and case types.

In addition to surgical training, didactics and research are critical components of residency training. Our data show that all programs continued with didactic training; however, almost all programs converted these training activities to online video conferencing. Interestingly, half of respondents perceived online didactics to have better educational value than traditional in-person sessions, warranting further evaluation of the benefits of virtual didactics in residency education under more typical training circumstances. Also, it might be beneficial if residency programs created a contingency plan for complete conversion of didactics to an online format for situations similar to COVID-19. The increase in residency research activity reported by our respondents is encouraging and consistent with recommendations from others that residents use operative downtime to scale up certain research activities.<sup>17</sup>

This study is limited by the self-selection process and the small number of participating programs. Also, the survey was developed for this study and was not validated before use. Data were reported by 1 lead resident identified by the participating institution; however, survey questions were designed to solicit program-level experience instead of individual experience, and questions were constructed to elicit responses of yes/no, more/less, increased/decreased, and so on that would be possible for the lead resident to provide. Furthermore, data may not be representative of the experience of all residency programs, particularly because some programs in geographical locations severely affected by COVID-19 did not participate. Overall neurosurgery operative volume was measured, and this metric does not capture case complexity and diversity, which are key features of neurosurgery training.

## CONCLUSIONS

The COVID-19 pandemic has had an unprecedented impact on all facets of health care, including neurosurgery residency training. This study documents a significant reduction in operative volume in selected neurosurgery residency programs. During the epoch of decreased surgical case volumes, neurosurgery residents engaged in productive and popular online didactics and research-related activities, resulting in increased research productivity. Given the dynamic and ongoing nature of the COVID-19 pandemic, the educational impact of reduced operative volume requires further evaluation and will perhaps inspire future successful strategies for mitigation.

## CRediT AUTHORSHIP CONTRIBUTION STATEMENT

**Zaid S. Aljuboori:** Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Formal analysis, Resources, Supervision. **Christopher C. Young:** Investigation, Writing - original draft, Writing - review & editing, Resources, Supervision. **Visish M. Srinivasan:** Investigation, Writing - review & editing. **Ryan T. Kellogg:** Investigation, Writing - review & editing. **Jennifer L. Quon:** Investigation, Writing - review & editing. **Mohammed A. Alshareef:** Investigation, Writing - review & editing. **Stephanie H. Chen:** Investigation, Writing - review & editing. **Michael Ivan:** Writing - review & editing. **Gerald A. Grant:** Writing - review & editing. **Sean D. McEvoy:** Investigation, Writing - review & editing. **Justin R. Davanzo:** Investigation, Writing - review & editing. **Sonia Majid:** Investigation, Writing - review & editing. **Sharon Durfy:** Writing - original draft, Writing - review & editing. **Michael R. Levitt:** Writing - review & editing. **Emily P. Sieg:** Writing - review & editing. **Richard G. Ellenbogen:** Writing - review & editing. **Haring J. Nauta:** Writing - review & editing.

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