Neurosurgery Subspecialty Practice During a Pandemic: A Multicenter Analysis of Operative Practice in 7 U.S. Neurosurgery Departments During Coronavirus Disease 2019

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■ OBJECTIVE: **Changes to neurosurgical practices during the coronavirus disease 2019 (COVID-19) pandemic have not been thoroughly analyzed. We report the effects of operative restrictions imposed under variable local COVID-19 infection rates and health care policies using a retrospective multicenter cohort study and highlight shifts in operative volumes and subspecialty practice.**

■ METHODS: **Seven academic neurosurgery departments' neurosurgical case logs were collected; procedures in April 2020 (COVID-19 surge) and April 2019 (historical control) were analyzed overall and by 6 subspecialties. Patient acuity, surgical scheduling policies, and local surge levels were assessed.**

■ RESULTS: **Operative volume during the COVID-19 surge decreased 58.5% from the previous year (602 vs. 1449, $P = 0.001$). COVID-19 infection rates within departments' counties correlated with decreased operative volume ($r = 0.695$, $P = 0.04$) and increased patient categorical acuity ($P = 0.001$). Spine procedure volume decreased by 63.9% (220 vs. 609, $P = 0.002$), for a significantly smaller proportion of overall practice during the COVID-19 surge (36.5%) versus the control period (42.0%) ($P = 0.02$). Vascular volume decreased by 39.5% (72 vs. 119, $P = 0.01$) but increased as a percentage of caseload (8.2% in 2019 vs. 12.0% in 2020, $P = 0.04$). Neuro-oncology procedure volume decreased by 45.5% (174 vs. 318, $P = 0.04$) but maintained a consistent proportion of all neurosurgeries (28.9% in 2020 vs. 21.9% in 2019, $P = 0.09$). Functional neurosurgery volume, which declined by 81.4% (41 vs. 220, $P = 0.008$), represented only 6.8% of cases during the pandemic versus 15.2% in 2019 ($P = 0.02$).**

■ CONCLUSIONS: **Operative restrictions during the COVID-19 surge led to distinct shifts in neurosurgical practice, and local infective burden played a significant role in operative volume and patient acuity.**

INTRODUCTION

Initial reports of severe acute respiratory syndrome coronavirus 2 came from Wuhan, China, in December 2019,[1] and the World Health Organization declared coronavirus disease 2019 (COVID-19) a pandemic by March 11, 2020.[2] A year later, nearly 119 million cases and >2.6 million deaths were attributed to COVID-19 worldwide, with >29 million cases and 530,713 deaths in the United States.[3]

An expected surge of COVID-19 patients needing critical care resources led the American College of Surgeons (ACS) to issue

Key words
- Acuity
- COVID-19
- Epidemiology
- Multicenter
- Neurosurgical subspecialty practice
- Pandemic

Abbreviations and Acronyms
ACS: American College of Surgeons
COVID: Coronavirus disease
GW: George Washington University

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Citation: World Neurosurg. (2022) 165:e242-e250.
https://doi.org/10.1016/j.wneu.2022.06.010

Journal homepage: www.journals.elsevier.com/world-neurosurgery

Available online: www.sciencedirect.com

recommendations on March 13, 2020, urging physicians to review elective surgical cases for possible rescheduling.[4] Health care governing bodies and national associations followed suit.[5,6] Hospital administrators and faculty subsequently formulated COVID-19—era surgical strategies. The ACS released another statement on March 17, 2020, acknowledging the limitations of a general call to restrict elective surgery.[7] Akin to paradigms for emergency surgery, the Elective Surgery Acuity Scale was presented, providing a 6-tier system based on pathologic acuity and patient health status. This clarification gave a window of "many months" versus the previous "weeks" of restriction, which created another challenge in rescheduling surgical procedures over a substantially longer time frame. Postsurgical critical care and its duration also were suggested as other surgical scheduling assessment parameters.[8]

These unprecedented circumstances and large increases in COVID-19 cases in March and April 2020[9] led to drastic local policies restricting surgeries. Many surgical subspecialties subsequently reported difficulties selecting patients and raised concerns about future backlogs and worsened patient outcomes.[10-13] Neurosurgery practice struggled to define the term *elective* when dealing with the body's least forgiving organ.[14,15]

We analyzed the effects of this public health crisis and its restrictions on neurosurgery subspecialty practice.

METHODS

This retrospective multicenter cohort study investigated the surgical practice of 7 U.S. academic neurosurgery departments at level 1 trauma centers throughout the United States, covering multiple patient populations and the COVID-19 epicenter during the study period, New York City. All neurosurgical patients during April 2020 (COVID-19 surge) and April 2019 (historical control) were included. Results are reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology guidelines. Institutional review board approval was obtained at every medical center. The study design and deidentified data analyses were compliant with the Health Insurance Portability and Accountability Act of 1996; patient consent was not required.

Neurosurgical case logs from April 2019 to April 2020 were acquired and analyzed to identify applicable patients. Pediatric patients (aged <18 years) and patients who received endovascular, intravenous, or intrathecal treatments were excluded. Pediatric patients were excluded because of inconsistent affiliation of all participating centers with a pediatric neurosurgery department. Endovascular, intravenous, and intrathecal procedures were excluded to enhance the focus on major surgical interventions requiring a traditional operating room environment. Electronic medical record review in addition to the case log allowed for collection of the following pooled data points: date of surgery, procedure name and duration, diagnosis, acuity of presenting symptoms, neurologic status, age, and sex. We also assessed the number of endonasal procedures because of reports of associated heightened infection risk.[16,17] Laxpati et al.[18] previously described unanticipated implications of COVID-19 restrictions on the volume of shunt surgeries, so we analyzed their frequency and type (new placement, revision, removal). Symptom acuity prompting surgery was used to allocate a patient acuity category: hyperacute (<3 hours), acute (3—24 hours), subacute (>24 hours to 7 days), and chronic (>7 days). We also analyzed the percentage of operated patients with intact preoperative neurologic status ("intact" or a Glasgow Coma Scale score of 15).

We defined 6 groups of neurosurgery subspecialty procedures: spine, neuro-oncology, vascular, functional, peripheral nerve, and general. General neurosurgery included procedures outside subspecialties; it consisted primarily of shunt placements, procedures to address infections (revisions, washouts), cranioplasties, and muscle and nerve biopsies. Departments provided detailed information on their surgical scheduling policy and its enforcement. The responses were either an internal determinant (the neurosurgery department alone) or an internal and external (e.g., hospital administrators) determinant on the final scheduling decision. COVID-19 infection rates were normalized to infections per 100,000 county residents and calculated using overall confirmed severe acute respiratory syndrome coronavirus 2 infections on April 30, 2020, in participating departments' counties from the USAFacts platform.[19]

Statistics and Data Analysis

Statistical analyses were performed with IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA). The alpha value was set at 5% with a significance level of $P < 0.05$. Continuous and categorical variables were analyzed with t-tests and χ^2 tests, respectively. Pearson correlation coefficients determined the relationship between county-level COVID-19 infection rates and operative volume change (1-tailed) or shifts in acuity levels (2-tailed).

RESULTS

Patient Demographics, Acuity Categories, and Neurologic Status

The median age of neurosurgical patients was less during the COVID-19 surge versus the control period (59 vs. 61 years, $P = 0.04$), although there is no clinical significance to this difference (Table 1). The female-male ratio declined significantly from 1.00 (719/722) in April 2019 to 0.85 (276/325) in April 2020 ($P = 0.001$). The shift in the mean operative time during the study was not significant (173 vs. 167 minutes, $P = 0.62$). The categorical designation of patient acuity changed from the prepandemic to the pandemic state ($P < 0.001$), with a decrease in patients with chronic state acuity (78.9%—55.9%) and an increase in patients with subacute (12.4%—26.1%) and acute (8.16%—17.8%) state acuity. In 5 departments with sufficient neurologic status data in the control period, 89.8% (924/1029) of patients were neurologically intact; this number decreased significantly to 60.0% (270/450) among 6 departments during the pandemic ($P = 0.008$).

Neurosurgery Practice During the Pandemic Surge

The 7 participating neurosurgery departments, although geographically isolated, provided representation from each of the 4 major U.S. geographic regions (Figure 1), as defined by the United States Census Bureau (West, Midwest, South, and Northeast).[20] Overall, operative volume decreased by 58.5% in April 2020 versus April 2019 (602 vs. 1449, $P < 0.001$) (Table 1). The volume for 5 procedure types decreased significantly ($P \leq 0.01$, Table 2):

Table 1. Demographics, Acuity, and Neurologic Status of Surgical Patients, Total and by Neurosurgery Department, During the Historical Control Month (April 2019) and Coronavirus Disease 2019 Surge (April 2020)

Variable	April 2019 (N = 1029)	April 2020 (N = 450)	Change	*P* Value
Age, median (IQR), year	61 (48—70)	59 (46—69)	−2 y	0.04*
Cornell	59	49		
Barrow	59	60		
UCSF	60	58		
UVA	63.5	57.5		
GW	54.5	59		
Georgetown	64	59		
U-M	60	59		
Patient sex ratio (female/male)	1.00 (719/722)	0.85 (276/325)	0.15	0.001*
Cornell	0.76	1.40		
Barrow	0.99	0.85		
UCSF	1.15	1.03		
UVA	1.06	0.78		
GW	0.44	0.73		
Georgetown	1.39	0.90		
U-M	0.93	0.48		
Patient acuity category, no. (%)				<0.001*
Chronic	812 (78.9)	252 (55.9)		
Subacute	128 (12.4)	117 (26.1)		
Acute	84 (8.16)	80 (17.8)		
Hyperacute	5 (0.5)	1 (0.2)		
Neurologically intact patients, %	89.8	60.0	−29.8%	0.008*
Cornell	77.9	8.3		
Barrow	89.5	80.5		
UCSF	NA	NA		
UVA	NA	34.4		
GW	87.1	79.0		
Georgetown	97.9	78.2		
U-M	96.5	79.7		
Number of surgical procedures	1449	602	−58.5%	<0.001*
Cornell	193	24		
Barrow	381	210		
UCSF	282	152		
UVA	138	64		
GW	62	38		
Georgetown	191	55		
U-M	202	59		

IQR, interquartile range; Cornell, New York-Presbyterian Hospital/Weill Cornell Medicine; Barrow, Barrow Neurological Institute; UCSF, University of California, San Francisco; UVA, University of Virginia; GW, George Washington University; Georgetown, Georgetown University; U-M, University of Michigan; NA, not available.
*Statistically significant.

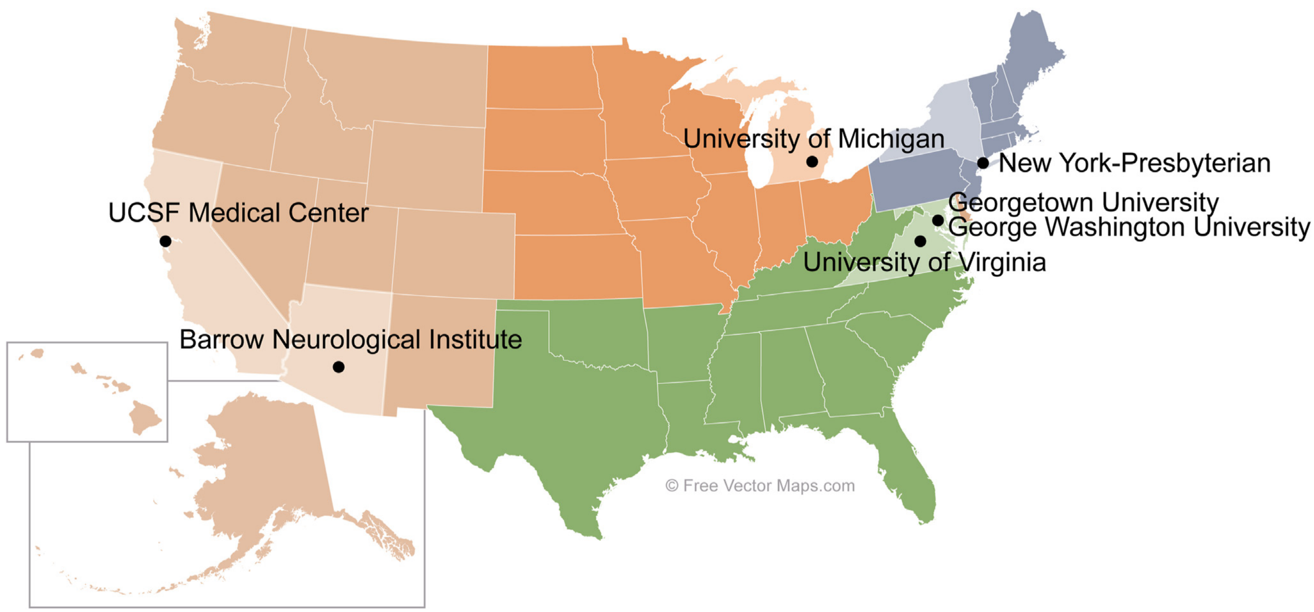

Figure 1. The U.S. map showing 7 neurosurgery departments that provided study data across the country, representing the 4 major geographic regions as defined by the United States Census Bureau (West, Midwest, South, and Northeast). West region (*brown shading*): University of California, San Francisco (USCF) Medical Center (San Francisco, CA) and Barrow Neurological Institute (Phoenix, AZ). Midwest region (*orange shading*): University of Michigan (Ann Arbor, MI). South region (*green shading*): University of Virginia (Charlottesville, VA), Georgetown University (Washington, DC), and George Washington University (Washington, DC). Northeast region (*blue shading*): New York-Presbyterian/Weill Cornell Medicine (New York, NY). *Used with permission from Free Vector Maps.*

spine, −63.9%; neuro-oncology, −45.3%; vascular, −39.5%; functional, −81.4%; and general, −46.6%. The decrease in peripheral nerve procedures (−59.1%) was not statistically significant ($P = 0.16$). Two departments performed no peripheral nerve procedures during 2019, and 6 departments performed none during 2020. The University of California, San Francisco, performed the most peripheral nerve procedures overall (8 in 2019 and 9 in 2020) (**Table 3**).

An important aspect of our analysis is the proportional shift of each neurosurgery subspecialty within the overall practice (**Figure 2**, **Table 2**). The largest shift was within functional neurosurgery (from 15.2% of all cases in 2019 to 6.8% in 2020,

Table 2. Changes in Neurosurgical Volume by Neurosurgery Subspecialty During the Coronavirus Disease 2019 Surge

Neurosurgery Subspecialty	April 2019 (Control)	April 2020 (COVID-19 Surge)	Case Volume		Proportional Shift	
			Number of Change (%)*	*P* Value	% Point Change	*P* Value
Spine	609	220	389 (−63.9)	0.002†	−5.5	0.02†
Neuro-oncology	318	174	144 (−45.3)	0.004†	+7.0	0.09
Vascular	119	72	47 (−39.5)	0.01†	+3.8	0.04†
Functional	220	41	179 (−81.4)	0.008†	−8.4	0.02†
Peripheral	22	9	13 (−59.1)	0.16	0	0.42
General	161	86	75 (−46.6)	0.01†	+3.2	0.16
Total	1449	602	847 (−58.5)	0.001†	NA	NA

COVID-19, coronavirus disease 2019; NA, not applicable.
*Case volume change represents the percentage change in case volume between April 2019 (historical control period) and April 2020 (COVID-19 surge).
†Statistically significant difference from April 2019 to April 2020. Proportional shift of overall practice for April 2020 versus April 2019.

Table 3. Changes in Neurosurgical Volume by Neurosurgery Subspecialty and Department During the Coronavirus Disease 2019 Surge versus the Historical Control Month*

Variable	Cornell	Barrow	UCSF	UVA	GW	Georgetown	U-M
COVID-19 surge							
County	New York	Maricopa	San Francisco	Charlottesville City	District of Columbia	District of Columbia	Washtenaw
Infection rate†	1346	89	170	118	613	613	292
Number of actual infections	21,920	3972	1499	56	4323	4323	1075
Surgical volume change, % (number of surgeries Apr 2020/Apr 2019)							
Spine	−91.8 (7/85)	−54.0 (63/137)	−52.3 (52/109)	−55.6 (28/63)	−18.8 (26/32)	−73.8 (28/107)	−78.9 (16/76)
Vascular	−76.9 (3/13)	−32.5 (27/40)	−6.3 (15/16)	−55.6 (4/9)	−44.4 (5/9)	−50.0 (7/14)	−38.9 (11/18)
Neuro-oncology	−88.5 (6/52)	−16.3 (72/86)	−40.0 (45/75)	−36.4 (21/33)	−85.7 (1/7)	−23.5 (13/17)	−66.7 (16/48)
Functional	−94.4% (1/18)	−81.0 (12/63)	+53.8 (18/39)	+61.1 (7/18)	−100 (0/3)	−100 (0/42)	−91.9 (3/37)
Peripheral	0 (0/0)	−100 (0/3)	+12.3 (8/9)	0 (0/0)	−100 (0/2)	−100 (0/1)	−100 (0/8)
General	−72.0 (7/25)	−30.8 (36/52)	−62.9 (13/35)	−73.3 (4/15)	−33.3 (6/9)	−30.0 (7/10)	−13.3 (13/15)
Total	−87.6 (24/193)	−44.9 (210/381)	−46.1 (152/282)	−53.6 (64/138)	−38.7 (38/62)	−71.2 (55/191)	−70.8 (59/202)

COVID-19, coronavirus disease 2019; Cornell, New York-Presbyterian Hospital/Weill Cornell Medicine; Barrow, Barrow Neurological Institute; UCSF, University of California, San Francisco; UVA, University of Virginia; GW, George Washington University; Georgetown, Georgetown University; U-M, University of Michigan.
*COVID-19 surge is defined as April 2020; the historical control period is defined as April 2019. The county corresponds to that in which the neurosurgery department is located.
†The number of COVID-19 infections per 100,000 residents registered on April 30, 2020.

$P = 0.02$). The percentage of spine procedures also declined (from 42.0% to 36.5%, $P = 0.02$), but the proportion of vascular procedures increased (from 8.2% to 12.0%, $P = 0.04$). Overall, neuro-oncology procedures remained unchanged (from 21.9% to 28.9%, $P = 0.09$); however, 1 department saw a decline in its proportion of neuro-oncology cases (2.6% in 2020 vs. 11.3% in 2019), while the other 6 departments combined increased their proportion of neuro-oncology procedures during the COVID-19 surge by 6.6 percentage points (28.7% vs. 22.1% of total cases, $P = 0.048$). The proportion of general and peripheral nerve procedures in neurosurgery practice did not change significantly ($P = 0.163$; $P = 0.42$).

The mean number of endonasal procedures performed among all departments decreased to 4.3 during the COVID-19 surge from 12.0 in April 2019 (30 vs. 84, $P = 0.01$); this 64.3% decrease in volume was greater than the overall decline in neurosurgical procedures (−58.5%), particularly neuro-oncology cases (−45.3%). No change in the total number of shunt procedures was reported during the COVID-19 period ($P = 0.16$). Shunt revisions, new placements, and removals showed no difference between 2020 and 2019 (13 vs. 15, $P = 0.72$; 21 vs. 49, $P = 0.15$; 3 vs. 3, $P > 0.99$, respectively).

Counties and Neurosurgery Departments

Neurosurgery departments were affected by a range of local COVID-19 surges in their home counties. New York County reported the highest rate of cases on April 30, 2020, with 1346 infections/100,000 residents (Table 3). The corresponding neurosurgery department at Weill Cornell Medicine (Cornell) observed the largest decrease in overall case volume (24 vs. 193 surgeries, −87.6%). Among the other study sites, county-level COVID-19 rates ranged from 613 to 89 infections/100,000 residents, while declines in case volumes ranged from −44.9% to −71.2%.

Importantly, the decreased volume of neurosurgical procedures correlated with local COVID-19 surges ($r = 0.695$, $P = 0.04$). Patient acuity also correlated moderately with local infection rates ($r = 0.367$, $P = 0.001$).

Local Policies

Four neurosurgery departments (Barrow Neurological Institute; University of California, San Francisco; University of Virginia; and Georgetown University) reported operative scheduling by their neurosurgery service alone, and 3 departments (Cornell, University of Michigan, and George Washington University [GW]) reported involvement of their external hospital administration and neurosurgery department. The reduction in operative volume was less for the departments with involvement of the hospital administration than for those with internal department input alone (−54.0% vs. −65.7%, $P = 0.001$).

Interestingly, the 2 Washington, DC, departments operated under different surgical scheduling policies while facing the same local infection rate. For external operative scheduling at GW, scheduled procedures were reviewed and assigned to 1 of 3 categories if postponed or canceled: no risk or morbidity, some morbidity, or significant morbidity/mortality. At Georgetown, neurosurgery leadership and the operating surgeon reviewed scheduled procedures at the departmental level, applying a risk-benefit assessment primarily based on a 2-month time frame assessing whether a procedure could be delayed without detriment

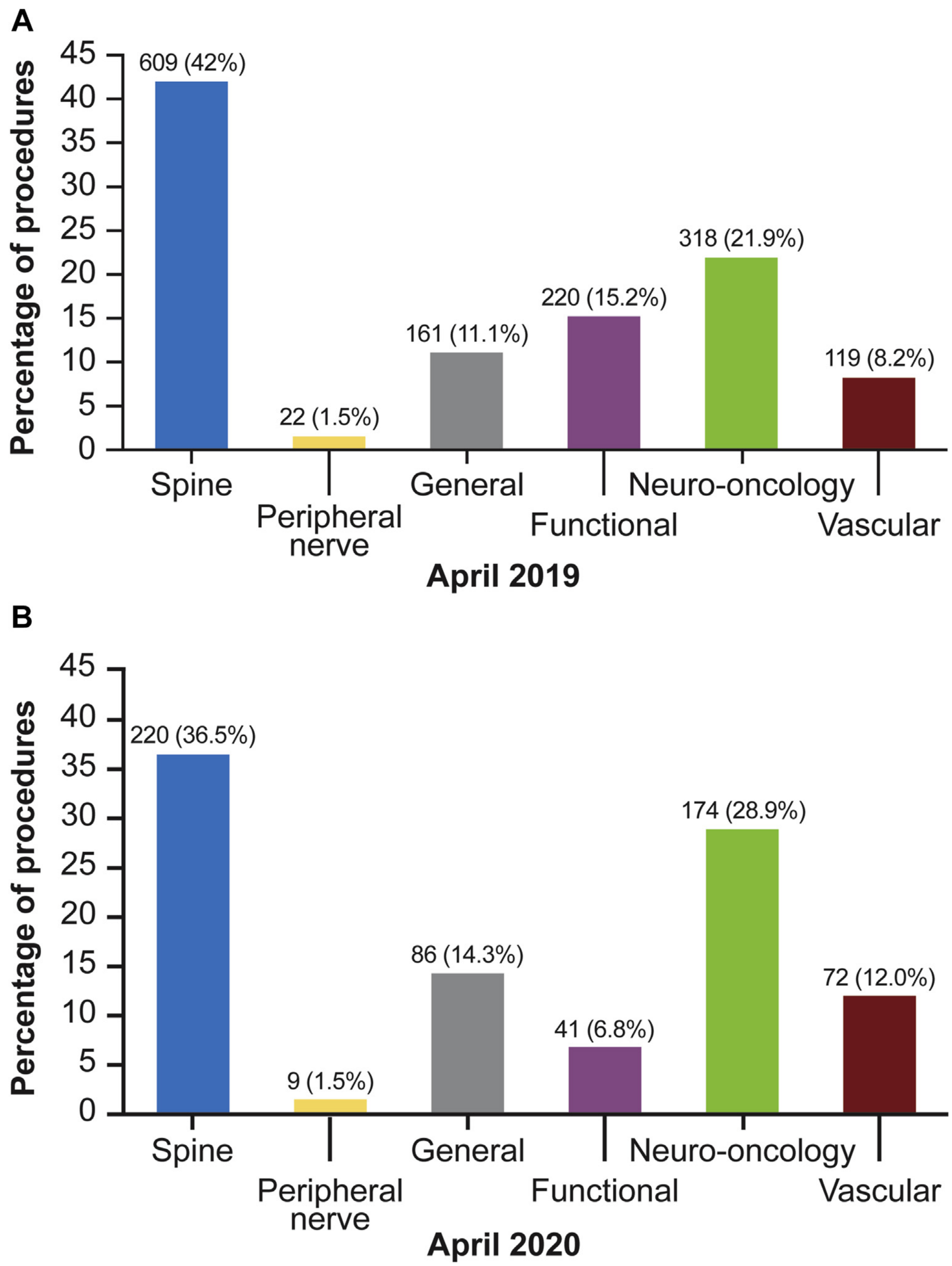

Figure 2. Number and relative proportions of neurosurgery procedures across all 7 academic medical centers. (**A**) April 2019, historical control (percentages total <100% due to rounding). (**B**) April 2020, COVID-19 era. *Used with permission from Barrow Neurological Institute, Phoenix, Arizona.*

to the patient's health. GW's operative caseload decreased by 38.7% (38 vs. 62), compared to Georgetown's decline of 71.2% (55 vs. 191) ($P = 0.001$). GW's experience contrasts with operative volume changes of the external scheduling group as a whole, where external influences produced steeper declines.

DISCUSSION

We identified a 58.5% decrease in neurosurgical caseload across 7 academic departments after the ACS issued elective surgery recommendations, similar to other reports on neurosurgical volume during COVID-19.[21,22] However, neurosurgery was not the only specialty dramatically affected in the early pandemic surge; inpatient otolaryngology procedures reportedly decreased by ≤ 60% in some regions, and orthopedic surgical cases decreased by 88%.[23,24]

We focused on neurosurgery subspecialty volumes to elucidate their distinct roles during limited surgical access. The proportion of open vascular and neuro-oncology procedures increased while that of spine and functional neurosurgery decreased. These differences are in line with the findings of single-center analysis by Ashkan et al.[22] and the assessments by 166 international neurosurgeons who ranked cases of cerebellar metastasis, glioblastoma, and giant aneurysms with the highest acuity among 9 hypothetical cases in the context of COVID-19 restrictions.[25] Although those cases do not represent the overall subspecialty practice and its necessity during a pandemic, they highlight the average acuity differences of each subspecialty's practice. Operative delays during the pandemic further emphasized the need for neurosurgeons to understand the natural course of nonacute pathologies when surgical delays may substantially alter the disease course and life expectancy. In addition to more dismal prospects, patients with intrinsic brain tumors faced more complicated surgeries and a larger tumor burden.[26] Despite a large number of elective procedures in spinal neurosurgery, spine procedures formed the largest proportion of operative volume during the COVID-19 surge in 6 of the 7 departments; neuro-oncology volume had the largest proportion in 1 department.

The significant decrease in our cohort's median age (59 vs. 61 years, $P = 0.04$) resembles that of a smaller cohort with a median age of 60 years,[27] while the female-male ratio, which changed to fewer women than men during the pandemic ($P = 0.001$), has not been analyzed before.

Our study included a wide range of local COVID-19 infection rates in the hospitals' catchment areas. Local infection rates correlated with the degree of operative volume loss ($r = 0.695$, $P = 0.04$), further highlighting the need for hospitals to implement infection risk-reduction measures among staff and patients.[28] Higher county rates of COVID-19 were correlated with increased categorical acuity of the surgical patient populations ($P < 0.001$), which ultimately reflects departments complying with elective surgery restrictions.

Early reports detailing additional infection risks for staff who performed endonasal surgery on COVID-19 patients came from Wuhan, China, on January 25, 2020.[29] Afterward, increased uncertainty about endonasal endoscopic techniques led to more scrutiny of these cases, with additional considerations of transcranial approaches as alternatives.[16] Although most efforts went into optimizing skull base practice to mitigate infection risks,[30,31] Workman et al.[32] investigated airborne aerosol-producing maneuvers and identified high-speed and suction drilling as well as nasal cavity cautery as the primary infection risks. These findings are reflected in the significant decline of endonasal procedures by 64.3% ($P = 0.01$). Notably, this decline was much larger than that for neuro-oncology surgeries, which comprise most endonasal indications yet only decreased by 45.3%.

Another important consideration during such a severe public health crisis is the shift in the number of procedures related to associated environmental factors (e.g., less travel and human contact, work from home). Several reports show a decline in stroke hospitalizations during the pandemic, which suggests environmental factors beyond the early assumption that patients who perceived hospitals as unsafe would avoid them.[33-35] In addition, a French study reported a sharp decline (52.1%) in musculoskeletal injuries in an emergency department during COVID-19 lockdowns.[36] In contrast to these examples, the reasons are less obvious for a reported decreased incidence of shunt surgeries, especially urgent revisions required by shunt failure.[18] Our analysis showed no significant changes in the incidence of shunt revisions, new placements, or removals.

Of the 2 departments in Washington, DC, GW had seemingly more restrictive operative scheduling policies (external operative scheduling) but a smaller loss in operative volume (−38.7%) than Georgetown, which used departmental operative scheduling (−71.2%) ($P = 0.001$) despite the same COVID-19 county surge at both hospitals. The smaller operative volume loss may be related to the baseline patient population. With both departments being at level-1 trauma centers, the lower rate of neurologically intact patients during the control period (GW vs. Georgetown, 87.1% vs. 97.9%; $P = 0.004$) suggests that GW generally treats a larger proportion of nonelective patients, who would be less affected by elective surgery restrictions.

These measures of the baseline neurosurgery patient population (i.e., prepandemic operative practice) could be useful parameters for hospital administrators, state legislators, and surgical associations developing guidance on surgical practice volumes and how departments can flex during crises. In March and April 2020, when the neurosurgical volume was unprecedentedly disrupted, such decisions were governed by uncertainty and an array of vague recommendations. Closer examination of operative volumes and how departments adapted their practice will help manage similar emergencies in the future.

Limitations

Although April 2020, the COVID-19 surge period we analyzed, marked a critical period of restricted operative practice, the unprecedented nature of these restrictions and their abrupt enforcement may skew the actual effects of operative restrictions in other circumstances. Although a month-long interval was adopted for data collection to survey the effects of the pandemic, this interval was not likely representative of the height of the pandemic across all the geographic regions provided in this study, thereby introducing selection bias. In addition, our hypotheses and correlations regarding reported categorical acuity are subject to subjective interpretation, limiting the generalizability of that assessment. Lastly, overall changes already occurring in neurosurgery practice, such as declines in open vascular neurosurgery volumes,[37] might have affected our comparison between the 2 periods.

CONCLUSION

Our analysis examined a cohort of 2051 patients from 7 academic neurosurgery departments treated during the COVID-19 pandemic and a similar period 1 year earlier. Results showed significant reductions in operative volume and volume shifts among neurosurgery subspecialties during restricted practice. Although operative numbers in all subspecialties decreased, neuro-oncology and vascular procedures had a prominent proportional increase in the overall neurosurgical practice. Functional and spine surgeries, as well as endonasal procedures, were disproportionally affected by the pandemic. County COVID-19 infection rates were directly related to larger decreases in operative volume and to the acuity of operations. The prepandemic acuity level of a department's operative practice is potentially linked to the restrictiveness of elective surgery required for that department. Given the dynamic nature of public health crises, neurosurgery departments should monitor their day-to-day operative practice, and governing bodies should use these data to maximize the applicability and efficacy of their recommendations and predictions.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Dimitri Benner: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Benjamin K. Hendricks:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – review & editing. **Cyrus Elahi:** Data curation. **Michael D. White:** Data curation. **Gary Kocharian:** Data curation. **Leonardo E. Albertini Sanchez:** Data curation. **Kyle E. Zappi:** Data curation. **Andrew L.A. Garton:** Data curation. **Joseph A. Carnevale:** Data curation. **Theodore H. Schwartz:** Supervision, Writing – review & editing. **Ehsan Dowlati:** Data curation. **Daniel R. Felbaum:** Supervision, Writing – review & editing. **Kenneth D. Sack:** Data curation. **Walter C. Jean:** Supervision, Writing – review & editing. **Andrew K. Chan:** Data curation. **John F. Burke:** Data curation. **Praveen V. Mummaneni:** Supervision, Writing – review & editing. **Michael J. Strong:** Data curation. **Timothy J. Yee:** Data curation. **Mark E. Oppenlander:** Supervision, Writing – review & editing. **Mariam Ishaque:** Data curation. **Mark E. Shaffrey:** Data curation. **Hasan R. Syed:** Supervision, Writing – review & editing. **Michael T. Lawton:** Supervision.

ACKNOWLEDGMENTS

The authors thank the staff of Neuroscience Publications at Barrow Neurological Institute for assistance with manuscript preparation.

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Conflict of interest statement: BKH is a consultant for Medtronic and owns patents licensed to Medtronic. PVM has served as a consultant for DePuy Spine, Globus, and Stryker; has direct stock ownership in Spinicity/ISD; has received royalties from DePuy Spine, Thieme Publishers, and Springer Publishing; and has received support from International Spine Study Group, Neurosurgery Research and Education Foundation, and AO Spine for non—study-related clinical or research effort.

Received 16 February 2022; accepted 2 June 2022

Citation: World Neurosurg. (2022) 165:e242-e250.
https://doi.org/10.1016/j.wneu.2022.06.010

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

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1878-8750/$ - see front matter