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Demand for Essential Nonambulatory Neurosurgical Care Decreased While Acuity of Care Increased During the Coronavirus Disease 2019 (COVID-19) Surge

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■ **BACKGROUND:** In times of health resource reallocation, capacities must remain able to meet a continued demand for essential, nonambulatory neurosurgical acute care. This study sought to characterize the demand for and provision of neurosurgical acute care during the coronavirus disease 2019 (COVID-19) pandemic.

■ **METHODS:** This single-center cross-sectional observational analysis compared nonambulatory neurosurgical consult encounters during the peri-surge period (March 9 to May 31, 2020) with those during an analogous period in 2019. Outcomes included consult volume, distribution of problem types, disease severity, and rate of acute operative intervention.

■ **RESULTS:** A total of 1494 neurosurgical consults were analyzed. Amidst the pandemic surge, 583 consults were seen, which was 6.4 standard deviations below the mean among analogous 2016–2019 periods (mean 873; standard deviation 45, $P = 0.001$). Between 2019 and 2020, the proportion of degenerative spine consults decreased in favor of spinal trauma (25.6% vs. 34% and 51.9% vs. 41.4%, $P = 0.088$). Among aneurysmal subarachnoid hemorrhage cases, poor-grade (Hunt and Hess grades 4–5) presentations were more common (30% vs. 14.8%, $P = 0.086$). A greater proportion of pandemic era consults resulted in acute operative management, with an unchanged absolute

frequency of acutely operative consults (123/583 [21.1%] vs. 120/911 [13.2%], $P < 0.001$).

■ **CONCLUSIONS:** Neurosurgical consult volume during the pandemic surge hit a 5-year institutional low. Amidst vast reallocation of health care resources, demand for high-acuity nonambulatory neurosurgical care continued and proportionally increased for greater-acuity pathologies. In our continued current pandemic as well as any future situations of mass health resource reallocation, neurosurgical acute care capacities must be preserved.

INTRODUCTION

In March 2020, the World Health Organization declared coronavirus disease 2019 (COVID-19) a global pandemic. Shortly thereafter, the United States declared a national emergency. This led to unprecedented changes in social, geopolitical, clinical, and health system determinants of health. Communities nationwide observed lockdowns involving stay-at-home orders, social distancing, school and nonessential business closures, international and interstate travel restrictions, and widespread work-from-home practices. The health care workforce responded by redeploying personnel, rationing personal protective equipment (PPE), and redesignating intensive care unit (ICU) and

Key words

- Acute care neurosurgery
- COVID-19 surge
- Pandemic preparedness
- Public health

Abbreviations and Acronyms

ARIMA: Autoregressive integrated moving average

aSAH: Aneurysmal subarachnoid hemorrhage

CI: Confidence interval

COVID-19: Coronavirus disease 2019

ED: Emergency department

GCS: Glasgow Coma Scale

HH: Hunt and Hess

ICU: Intensive care unit

OR: Operating room

PPE: Personal protective equipment

TBI: Traumatic brain injury

TSA: Time-series analysis

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Citation: World Neurosurg. (2021) 151:e523–e532.

<https://doi.org/10.1016/j.wneu.2021.04.080>

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

Available online: www.sciencedirect.com

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operating room (OR) resources toward COVID-19–related and nondeferrable non-COVID-19–related disease.

Effects of such measures were seen, with reports worldwide of increased excess mortality,^{1,2} decreased emergency department (ED) visits³ and decreased admissions for myocardial infarction.^{4,5} Some have estimated that the economic impact of COVID-19 on the United States could reach \$16 trillion, accounting for recession-, morbidity-, and mortality-related losses.^{6,7} Accordingly, providers appealed to patients to continue seeking non-COVID-19–related acute care despite the “dread risk” of the pandemic.^{8,9} As the pandemic and its waves continued, institutions were faced with the challenge of fostering safe provision of this care. Neurosurgery was not spared from these impacts. While “deferrable” elective neurosurgical procedures were on hold through the early pandemic surge, emergency and “essential” neurosurgical care continued despite restrictions on the personnel, PPE, OR, and ICU resources required to meet this demand.

Our study assessed the demand for and provision of acute neurosurgical care during the COVID-19 pandemic, quantifying the effects of the lockdown on patients presenting for non-ambulatory neurosurgical care at a single tertiary care academic hospital in New England during the early “surge” of patients in the United States, which affected the Northeast most prominently. We compared the volume of consults to the inpatient neurosurgery service between the pandemic period in 2020 to its analogous calendar period in 2016–2019. We characterized the nature, disease severity, and end points of these consults in 2020 and 2019.

METHODS

This single-center, cross-sectional, observational analysis was conducted at Rhode Island Hospital, a 700-bed tertiary care academic facility in Providence, Rhode Island. This facility is the sole Level I Trauma Center the sole level I trauma center in the Rhode Island region of Southeast New England and the only hospital with in-house on-call in-person neurosurgical services available 24/7 in its state.

After obtaining institutional review board approval (#1597269), neurosurgical consult notes from 2016 to 2020 were collected using an electronic medical record database search. The time frame chosen encompassed the start of the state’s lockdown (3/16/2020) through the initiation of Reopening Phase I (5/8/2020), representing a period of closure of nonessential businesses, social distancing, remote learning at schools, widespread work-from-home practices, and stay-at-home precautions. Biweekly volumes were calculated and graphed, comparing 2020 with 2016–2019 to examine volume variability over a 5-year period. Consult characteristic data were abstracted from the years of 2019 and 2020, for the March 9 to May 31, 2020, period, chosen a priori to encompass the start of the state’s lockdown (3/16/2020) through the initiation of Reopening Phase I (5/8/2020). Consult notes were reviewed for patient demographics, problem type, and whether the consult resulted in acute surgical management (e.g., the patient underwent an OR procedure during the same admission or within a few days thereafter). Presenting Glasgow Coma Scale (GCS) scores and Hunt and Hess (HH) grades were collected for traumatic brain

injury (TBI) and aneurysmal subarachnoid hemorrhage (aSAH) subgroups.

Univariate analysis was performed to assess differences in the distribution of these variables between 2019 and 2020 cohorts, using Mann–Whitney U and χ^2 tests for continuous and categorical variables, respectively. Multivariate analysis was performed using interrupted time–series analysis (TSA) to assess for changes in consult volumes between cohorts while adjusting for seasonal variations. An autoregressive integrated moving average (ARIMA) linear spline model was used to study the impact of an exogenous factor (onset of pandemic lockdown and surge) while adjusting for other temporal trends.^{10,11}

Statistical analysis was completed using STATA (Stata Release 15; StataCorp LP, College Station, Texas, USA). Graph construction and TSA were completed using R (R Version 3.5.3; R Foundation for Statistical Computing, Vienna, Austria; “TSA” package).

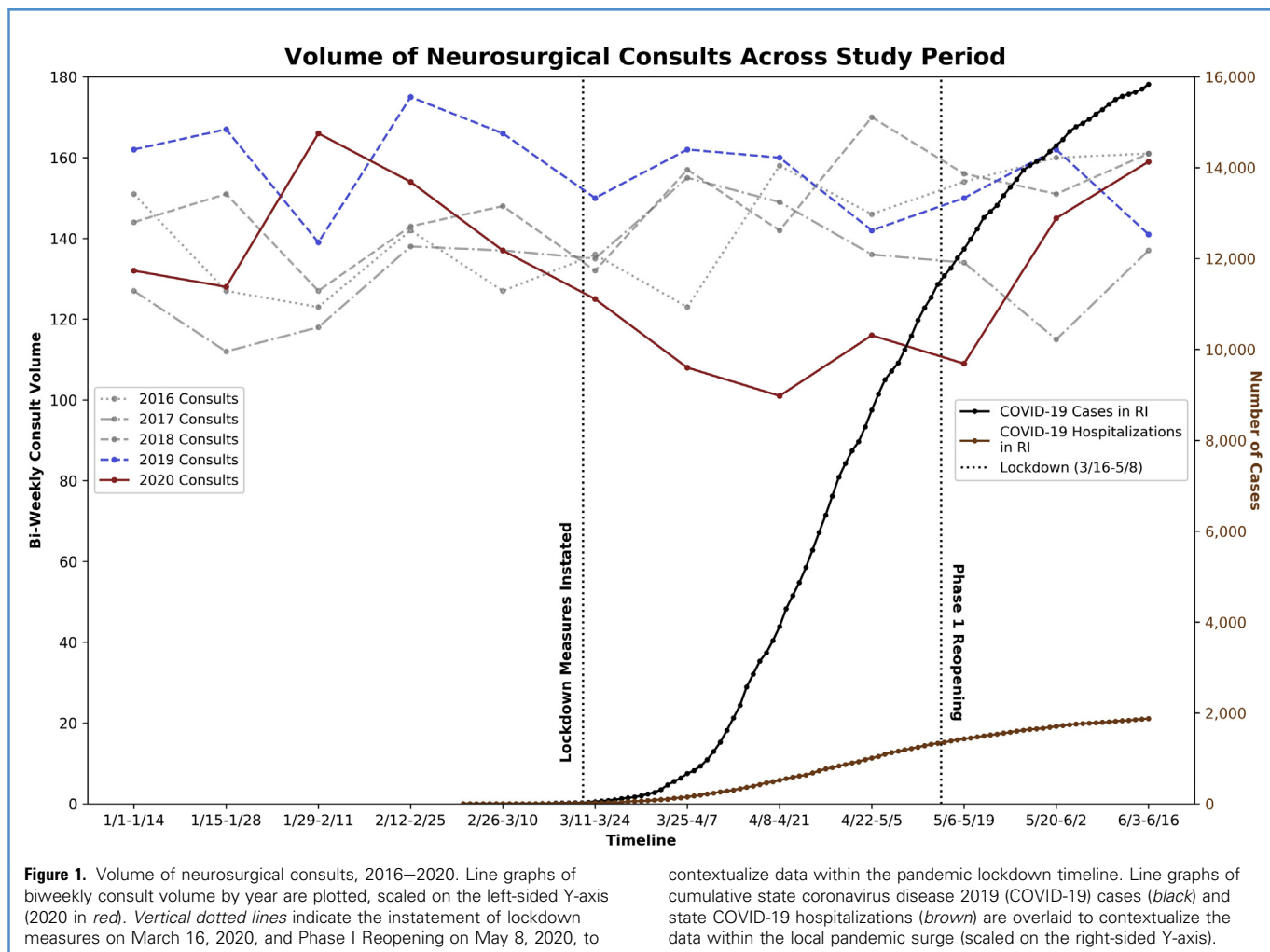
RESULTS

During the pandemic lockdown and surge period, consult volume reached a 5-year low. **Figure 1** demonstrates volume decreasing significantly after state lockdown instatement and increasing back toward conventional volumes after Phase I reopening. This decline in demand for nonambulatory neurosurgical care was great: 583 nonambulatory consults were seen by the neurosurgical service in the 2020 period, which is 6.4 standard deviations below the same calendar period’s average among the years 2016–2019 (mean 873, standard deviation 45, $P = 0.001$). A multivariate time–series model confirmed that this decrease in consult volume was independent after adjustment for seasonal trends. ARIMA modeling demonstrated 22.5 fewer consults per week on average ($P < 0.001$). Cranial and spine subgroups saw 13.2 ($P = 0.014$) and 9.3 ($P < 0.001$) fewer average weekly consults, respectively. Within 2020 itself, there were 18.6 fewer average weekly consults during the lockdown (3/16/2020–5/8/2020) compared with the periods preceding and following ($P < 0.001$).

Further data were abstracted for 2020 and 2019, totaling 1,494 consults (**Table 1**). Demographic characteristics were similar between periods. There was a slight increase in the proportion of consults classified as cranial (72.6% vs. 70.6%, $P = 0.044$, **Figure 2A**). These included cranial trauma (43.0%), tumor (17.8%), vascular (15.1%), hydrocephalus (8.9%), stroke and intracerebral hemorrhage (0%), and other pathologies. There was a relatively equal volume decrease across all cranial pathologies, with no difference in the distribution of cranial problem types between pandemic and nonpandemic years ($P = 0.151$) (**Figure 2B**).

Among the 428 spine consults seen, consults related to degenerative disc disease pathology comprised a smaller proportion of overall consults in the pandemic era. The distribution, in turn, favored spinal trauma (degenerative disc disease: 41/159 in 2020 [26%, 95% confidence interval {CI} 20%–33%] vs. 91/268 in 2019 [34%, 95% CI 29%–40%]; trauma: 83/159 [52%, 95% CI 44%–60%] vs. 111/268 [41%, 95% CI 35%–47%]; $P = 0.088$, **Figure 2C**). Other spinal consults included infection, tumor, vascular, and other issues.

Severity at presentation was characterized for TBI and aSAH subgroups using GCS scores and HH grades upon presentation. A



larger proportion of pandemic-era aSAH consults presented as poor-grade (HH grades 4–5; 9/30 in 2020 [30%, 95% CI 17%–48%] vs. 9/61 in 2019 [15%, 95% CI 8%–26%]; $P = 0.086$; **Figure 3**). Among the TBI population, however, there was no difference in the distribution of mild, moderate, or severe GCS scores between years, with most consults continuing to involve mild TBI.

The number of cases requiring acute operative intervention, in absolute terms, was unchanged across prepandemic and pandemic years, and such cases comprised a larger proportion of pandemic era consults (123/583 in 2020 [21%, 95% CI 18%–24%] vs. 120/911 in 2019 [13%, 95% CI 11%–15%]; $P < 0.001$; **Figure 4A**). This was observed among both cranial and spine consults (**Figure 4B–E**). Among cranial consults, there was a 59% increase in the proportion of acutely operative cases (88/423 in 2020 [21%, 95% CI 17%–25%] vs. 83/643 in 2019 [13%, 95% CI 10%–16%]; $P = 0.006$). Among spine consults, there was a 67% increase in the proportion of acutely operative consults (37/160 in 2020 [23%, 95% CI 17%–30%] vs. 37/268 in 2019 [14%, 95%

CI 10%–18%]; $P = 0.014$). Other management end points included palliative or end-of-life directed management, bedside neurosurgical interventions, and “other” (e.g., nonoperative management, admission for observation, outpatient follow up, or no neurosurgical management) (**Table 1**).

DISCUSSION

The COVID-19 pandemic has exerted unprecedented influences on global and regional health care systems as well as non-COVID-19–related disease. The Spring 2020 pandemic surge in Rhode Island was moderate in comparison with other locales on the world stage, with a peak weekly incidence rate of 190/100,000 during the early surge (peaking the week of 4/19/2020).¹² Nevertheless, lockdown measures were similarly maximal, including closure of nonessential businesses, social distancing, remote learning at schools, widespread work-from-home practices, and stay-at-home precautions. One Global Positioning System report

Table 1. Neurosurgical Consults, March 9 to May 31, 2019 Versus 2020

Variable	2019 and 2020 (Total) (n = 1494) Frequency (%)	2019 (n = 911) Frequency (%)	2020 (n = 583) Frequency (%)	P Value (2019 vs. 2020)
Age, y, median [IQR]	61.5 [43–76]	62 [41–76]	61 [45–75]	0.510
Race and ethnicity				0.921
White	1145 (76.6%)	705 (77.4%)	440 (75.5%)	
Hispanic	175 (11.7%)	105 (11.5%)	70 (12.0%)	
Black	96 (6.4%)	57 (6.3%)	39 (6.7%)	
Asian	24 (1.6%)	14 (1.5%)	10 (1.7%)	
Other	36 (2.4%)	19 (2.1%)	17 (2.9%)	
Refused or unknown	18 (1.2%)	11 (1.2%)	7 (1.2%)	
Consult location				0.728
ED	1244 (83.3%)	761 (83.5%)	483 (82.9%)	
Inpatient	250 (16.7%)	150 (16.5%)	100 (17.1%)	
Consult category				0.044*
Cranial	1066 (71.4%)	643 (70.6%)	423 (72.6%)	
Spine	411 (27.5%)	262 (28.8%)	149 (25.6%)	
Cranial and spine	17 (1.1%)	6 (0.7%)	11 (1.9%)	
Cranial: consult type (n = 1083)				0.151
Trauma	466 (43.0%)	273 (42.1%)	193 (44.5%)	
Tumor	193 (17.8%)	110 (17.0%)	83 (19.1%)	
Vascular	164 (15.1%)	96 (14.8%)	68 (15.7%)	
Hydrocephalus	96 (8.9%)	67 (10.3%)	29 (6.7%)	
Stroke and ICH	96 (8.9%)	55 (8.5%)	41 (9.5%)	
Other	37 (3.4%)	28 (4.3%)	9 (2.1%)	
Non-neurosurgical issue	31 (2.9%)	20 (3.1%)	11 (2.5%)	
Spine: consult type (n = 428)				0.088
Trauma	194 (45.3%)	111 (41.4%)	83 (51.9%)	
Degenerative disc disease	132 (30.8%)	91 (34.0%)	41 (25.6%)	
Other†	102 (24.4%)	66 (24.6%)	35 (22.5%)	
GCS on presentation, TBI subgroup (n = 378)		(n = 273)	(n = 193)	0.451
3–8	40 (10.1%)	22 (9.4%)	18 (11.2%)	
9–12	21 (5.3%)	15 (6.4%)	6 (3.7%)	
13–15	335 (84.6%)	198 (84.3%)	137 (85.1%)	

Continues

Table 1. Continued

Variable	2019 and 2020 (Total) (n = 1494) Frequency (%)	2019 (n = 911) Frequency (%)	2020 (n = 583) Frequency (%)	P Value (2019 vs. 2020)
HH grade on presentation, aSAH subgroup (n = 91)		(n = 61)	(n = 30)	0.086
HH 1–3	73 (81%)	52 (85%)	21 (70%)	
HH 4–5 (poor grade)	18 (19%)	9 (15%)	9 (30%)	
Consult management end point				<0.001*
Acute operative intervention	243 (16.2%)	120 (13.2%)	123 (21.1%)	
Bedside intervention	39 (2.6%)	24 (2.6%)	15 (2.6%)	
Palliative/EOL management	72 (4.8%)	39 (4.3%)	33 (5.7%)	
Other‡	1140 (76.3%)	729 (79.9%)	412 (70.7%)	

IQR, interquartile range; ED, emergency department; ICH, intracerebral hemorrhage; GCS, Glasgow Coma Scale; TBI, traumatic brain injury; HH, Hunt and Hess; aSAH, aneurysmal subarachnoid hemorrhage; EOL, end of life.

Neurosurgical consults are compared between 2019 and 2020, detailing demographics, consult location, problem type, management end point, and disease severity for the TBI and aSAH subgroups.

χ^2 tests were used to determine significant differences for categorical variables. Nonparametric Mann–Whitney *U* tests were used to determine significant differences for continuous variables. Percentages may not add up to 100% due to rounding. Consults categorized as “cranial and spine” were included in tabulations for both cranial and spine neurosurgery admissions.

*Denotes significance.

†Categories included in other for spine consults include infection, tumor, vascular, and non-neurosurgical issues.

‡“Other” consult management end point can include nonoperative management, outpatient follow-up, admit for observation, or no neurosurgical management necessary whatsoever.

showed a 30%–60% decrease in local traffic congestion during the early pandemic.¹³

These lockdown measures and surge effects were associated with a striking decrease in demand for nonambulatory neurosurgical care. Neurosurgical consult volume hit a 5-year institutional low, with a significant decline after the state lockdown was instated on March 16, 2020, followed by an increase back towards typical volumes after Phase I reopening on May 8, 2020 (Figure 1). Yet more of these encounters were of increased acuity, including poor-grade aSAH presentations as well as consults resulting in acute operative intervention, even in a time when OR and ICU resources were allocated under great scrutiny.

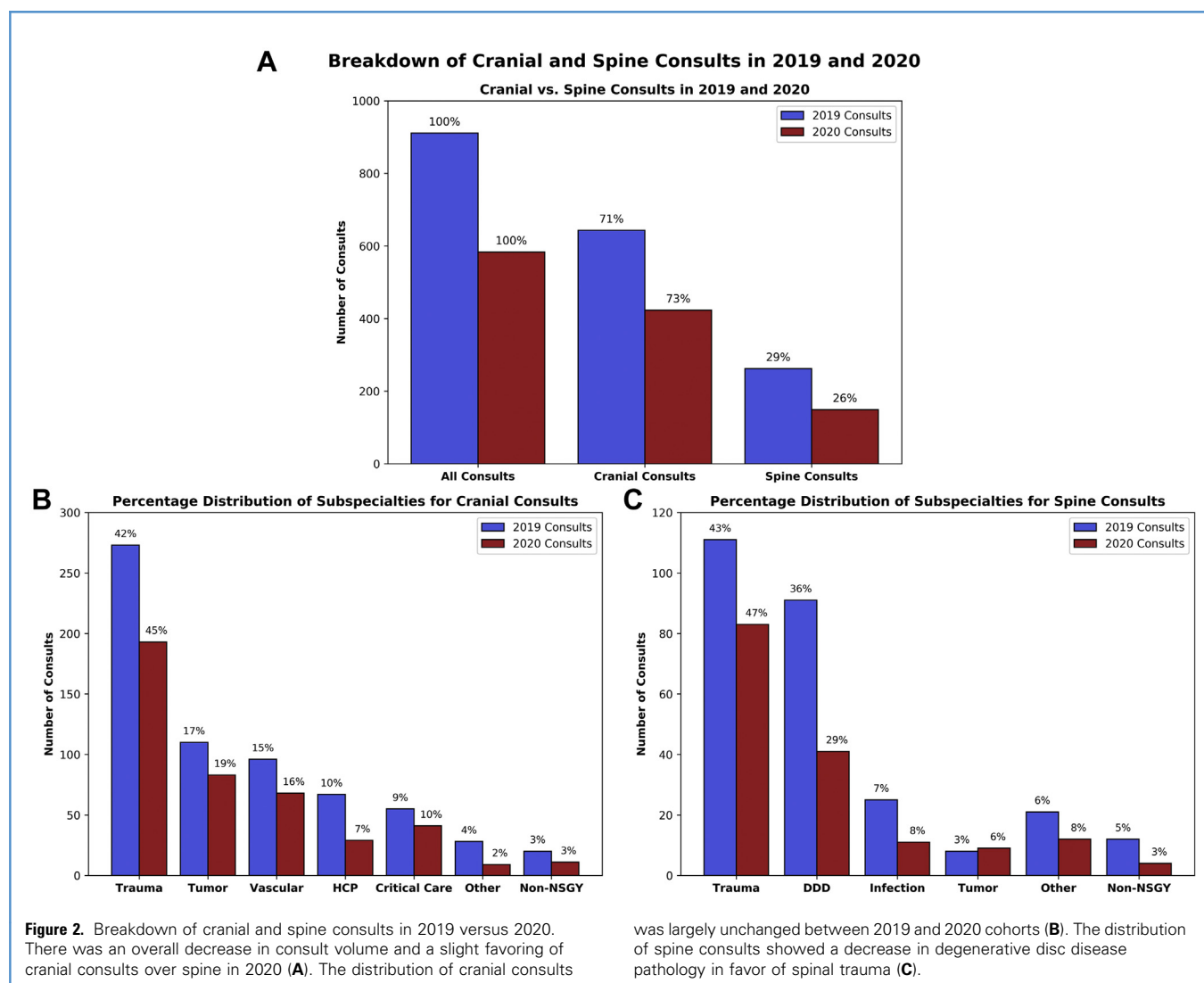
Worldwide, many also reported volume variations in stroke and myocardial infarction during the early pandemic, along with speculation about their cause.¹⁴ During the spring 2020 COVID-19

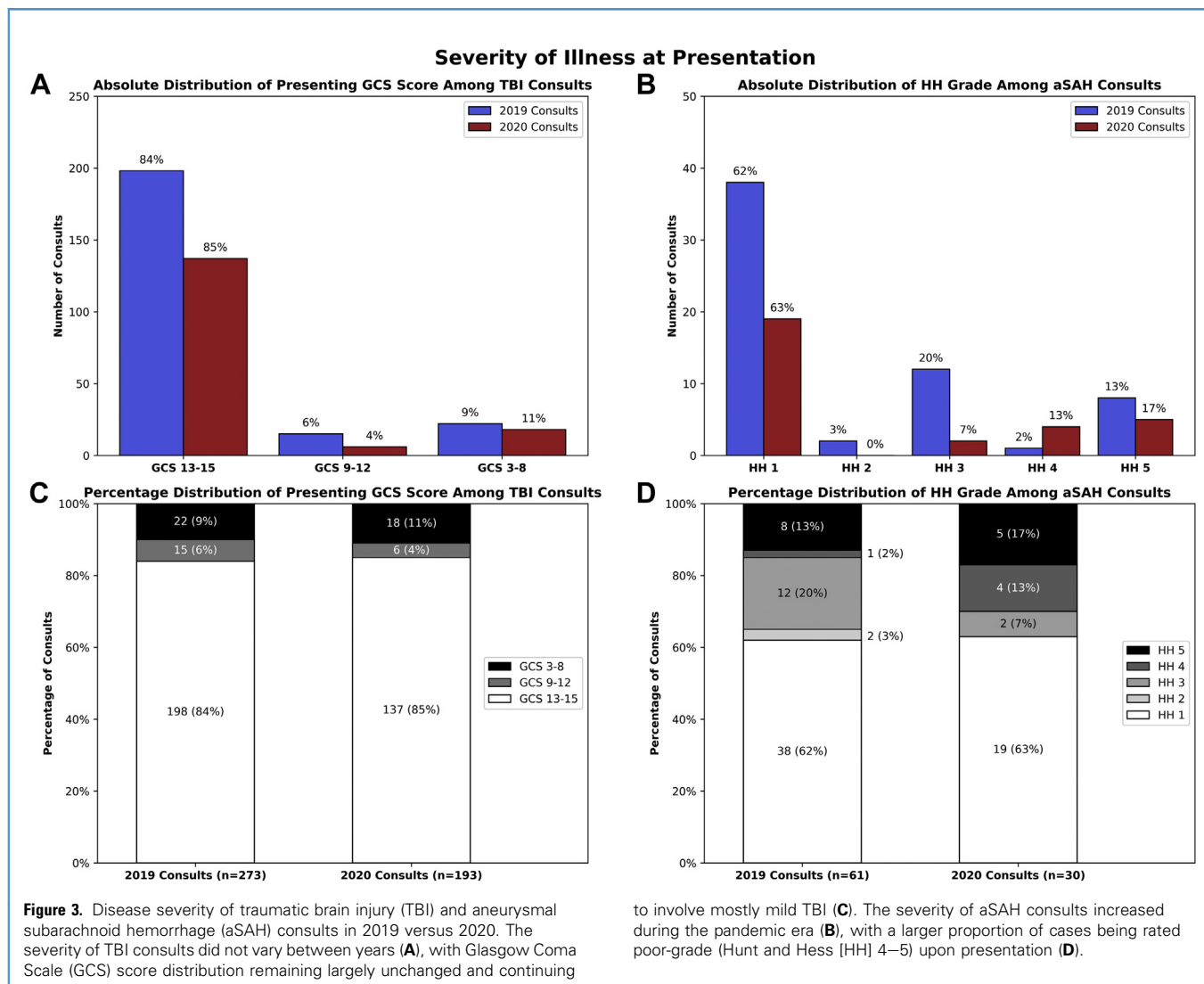
surge, admissions for acute myocardial infarction were significantly reduced in Italy⁴ and the United States,⁵ concomitant with a marked increase in Google search volume for “chest pain,”¹⁵ followed by a spike in the U.S. mortality rate for heart disease.² ED code strokes, stroke admissions, and thrombectomy volumes declined across Barcelona,¹⁶ Hong Kong,¹⁷ China,¹⁸ Boston, New York City, Providence, Seattle, and Texas.¹⁹⁻²¹ In Hong Kong, patients with stroke presented significantly later than usual following symptom onset.¹⁷ In New York City, symptom onset-to-door time was not significantly different, but pandemic patients had greater mean National Institutes of Health Stroke Scale scores and increased odds of in-hospital mortality.¹⁹

Similar reports emerged in neurosurgery. In Milan, a multi-center study showed an 87% reduction in ED encounters for low back pain, with authors suggesting that patients were avoiding the hospital.²² In England, one Level I trauma center found a significant decrease in all neurosurgical referrals, with

significantly larger decreases for degenerative spine and TBI, citing a decrease in road traffic and patient avoidance as possible factors.²³ In Berlin, there was a 40% decline in admissions for neurosurgical emergencies, true for vascular, spinal, and hydrocephalus emergencies, with delayed care-seeking seen in spinal emergencies.²⁴ In Lombardy, a dramatic decrease in neurosurgical emergency procedures and admissions was seen in the first 2 weeks of lockdown, true for trauma as well as aSAH, among other pathologies.²⁵ Significant declines in aSAH admissions also were reported in Paris and Toronto.^{26,27} In Finland, however, the number of neuro-ICU admissions for TBI and aSAH remained stable, as did their outcomes.²⁸

In our cohort, significant decreases in consult volume were seen across all neurosurgical pathologies. Some pathologies may have been reduced by natural history factors (such as triggers for aneurysmal rupture, decreased road traffic, decreased labor), while all pathologies were likely reduced by social factors. Patients

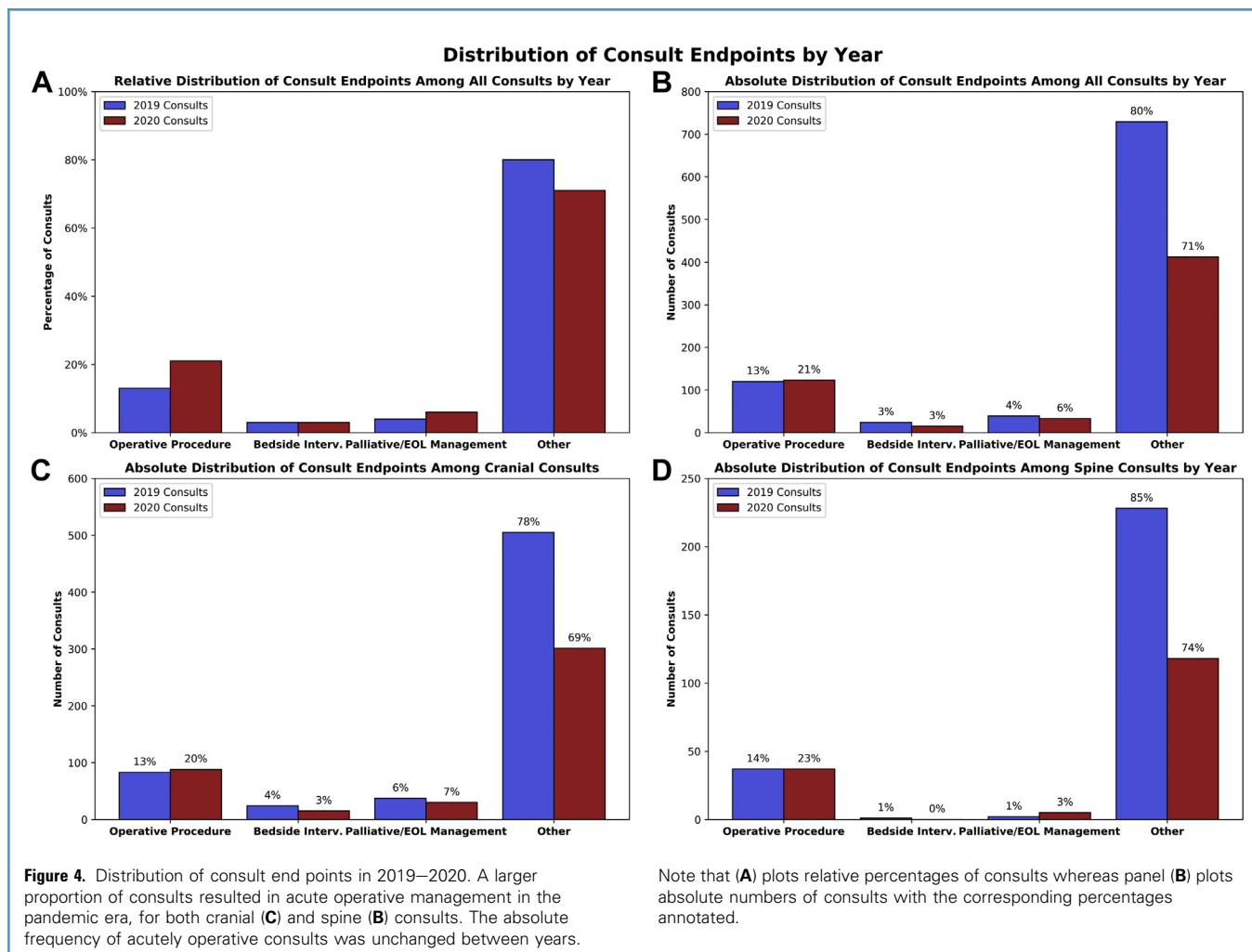




likely exercised discretion in going to the hospital amidst a pandemic, fearing contagion or reluctant to burden the health care system. Social isolation may have reduced symptom detection and ultimately delayed or altogether prevented presentation to the health care system. Those developing altered mental status while living or working in isolation, for example, would have nobody to note their symptoms. We did unfortunately find a larger proportion of poor-grade aSAH in our pandemic cohort, and it is possible that some of these patients had nobody around them to notice their symptoms and bring them to care at symptom onset (when they may have been more favorable HH grade 1–3 cases), leading to progression before presentation. Other socially isolated patients may have died at home of neurosurgical disease, with nobody to notice their symptoms and bring them to the hospital at all. Still others who would have become neurosurgical patients in this time may have instead died of COVID-19 or other pandemic-related causes. Alas, such deaths may be captured in the period's

excess mortality statistics.^{6,7} Finally, the predominance of COVID-19 workup and diagnosis may have paradoxically “blinded” providers from including non-COVID-19 disease on their differentials, delaying diagnosis of true neurosurgical disease. We have included one case example of this behavior in Figure 5, illustrating a delayed diagnosis of giant pituitary adenoma resulting in acute pituitary apoplexy, hydrocephalus, and blindness. This patient had visited an urgent care facility 1 week prior with similar but milder symptoms and had been sent home after a negative COVID-19 test.

Thankfully, as our number of acutely operative consultations did not differ between pre- and peripandemic times, it seems that many patients who truly needed acute neurosurgical care did ultimately present for and receive it despite resource reallocations. During the Spring 2020 surge in the United States, the capacity available to meet a continued demand of essential neurosurgical care was greatly altered. In many hospitals including ours, neurosurgery

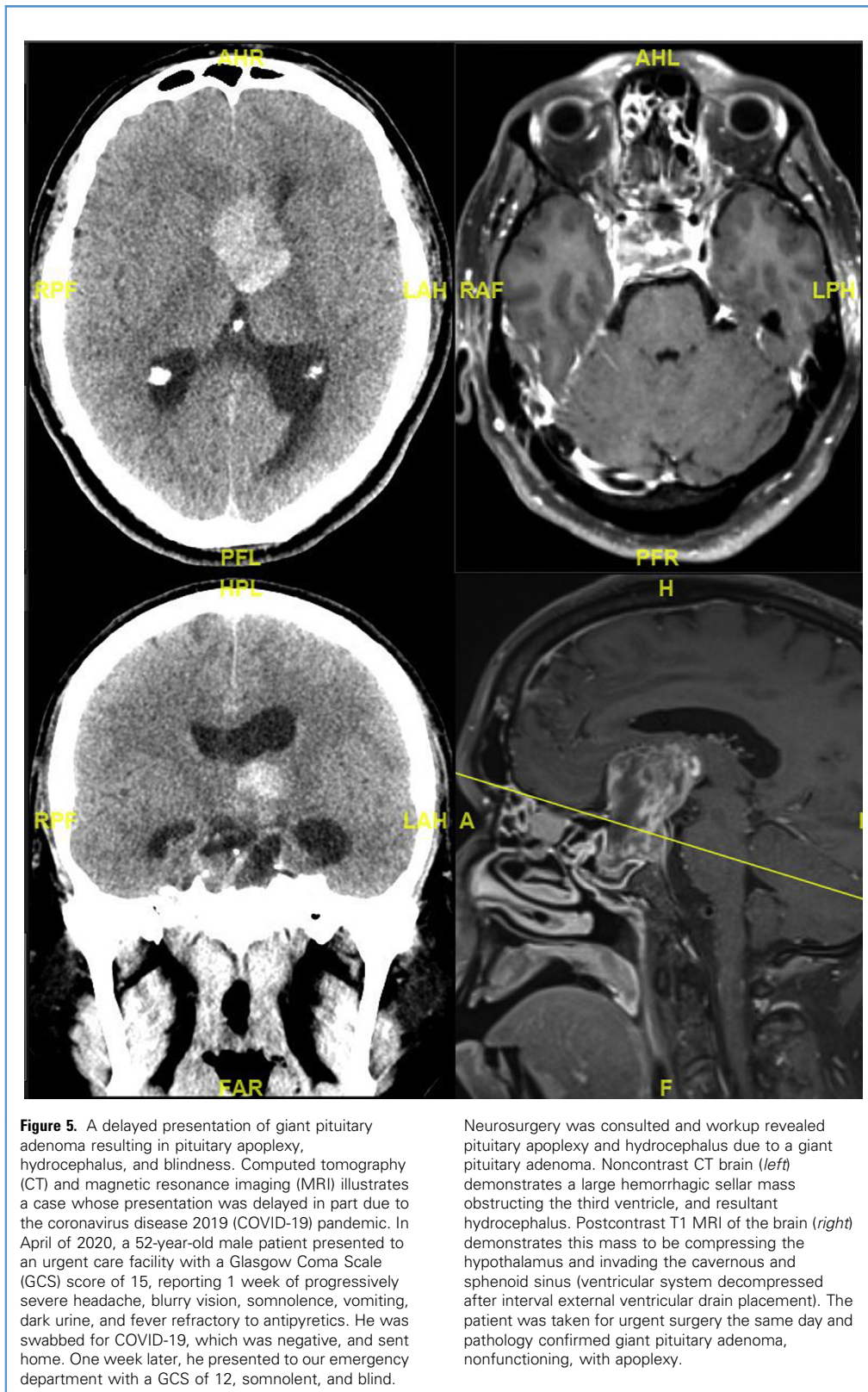


personnel were staffing ICUs, OR resources were greatly reduced, neurocritical care unit beds and personnel were diverted toward patients with COVID-19, and the neurosurgical call team was restructured into rotating skeleton cohorts to reduce potential viral transmission and exposure. Deferrable elective neurosurgical procedures were postponed, a choice made to help allow reallocation of health care capacities, especially PPE and ICU beds. Evidently, however, nonambulatory neurosurgical needs continued, and many patients in our analysis did require OR or ICU care. They received this despite the barriers: the booking of non-life-threatening cases was approved only after review by a departmental panel and then interdepartmental committee, and neurosurgical patients requiring ICU level of care were diverted to a converted cardiac stepdown and cardiothoracic ICU, given that our neurocritical care unit was redeployed as a COVID-19 ICU.

As our data show, acute neurosurgical needs cannot be controlled or postponed. Patients requiring urgent or emergent neurosurgical intervention will always be at our door, no matter the global milieu. Thankfully, our service was able to provide this

care and even offer an unchanged number of acute surgeries, despite institutional limitations. As the world reopened, redeployment measures dissolved, and “elective” surgeries resumed. Although the nightmarish early surge feels far behind us and vaccinations abound, the end of the pandemic is unknown. Continued “waves” may include both COVID-19–related illness as well as the burden of disease whose care was deferred during the lockdown. Our analysis highlights the importance of preserving the OR, PPE, ICU, and personnel resources necessary to meet the continued demand for essential, nonambulatory neurosurgical care no matter the circumstances.

Several factors limit the scope and generalizability of this analysis. This is a single-center, cross-sectional, observational study comparing institutional trends and therefore unable to report population incidence or prevalence. However, all ED cases presenting to any facility in the state that require nonambulatory neurosurgical care as well as Level I trauma care are referred to our center, so a large proportion of the state’s neurosurgical disease may be represented here. Still, many systems factors affecting



prehospital circumstances are unmeasurable, such as interhospital transfer dynamics, ambulance triage, and patients with neurosurgical problems who did not present for care at all. Multicenter studies or claims-based analyses may be able to elucidate population-level trends in future study. Regarding the severity of disease, we collected GCS and HH grades, as they are easily accessible in our records, and serve as well-validated ordinal severity scores. However, the disparate nature of other neurosurgical diseases precludes widescale characterization of disease severity. Future database-style studies may benefit from using additional metrics, such as the Injury Severity Score in polytrauma cases. Finally, our sample size and power were limited. We analyzed a 5-year sample to assess volume-based trends, which provided a well-powered sample to demonstrate stark differences in our ARIMA modeling analysis. However, we limited consult characteristic data to a 2-year sample for feasibility purposes. Further studies could include a review of additional years or multiple institutions' data for consult characteristics to provide an additional check that consult characteristic variation were not simply unique between 2019 and 2020 at our institution.

CONCLUSIONS

In this single-center cross-sectional analysis, neurosurgical consult volume during the COVID-19 pandemic surge hit a 5-year institutional low. Nevertheless, demand for high-acuity non-ambulatory neurosurgical care continued and proportionally increased for consults requiring acute operative intervention,

nondegenerative spine, and poor-grade aSAH. Amidst the continued current pandemic as well as any future mass reallocation of health resources, preservation of neurosurgical acute care capacities must be maintained.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Belinda Shao: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Validation, Writing - original draft, Writing - review & editing. **Oliver Y. Tang:** Data curation, Formal analysis, Investigation, Software, Validation, Visualization, Writing - review & editing. **Owen P. Leary:** Data curation, Project administration, Resources, Writing - review & editing. **Hael Abdulrazeq:** Data curation, Writing - review & editing. **Rahul A. Sastry:** Data curation, Writing - review & editing. **Sarah Brown:** Data curation, Project administration, Writing - review & editing. **Ira B. Wilson:** Conceptualization, Methodology, Supervision, Writing - review & editing. **Wael F. Asaad:** Conceptualization, Methodology, Supervision, Writing - review & editing. **Ziya L. Gokaslan:** Conceptualization, Methodology, Supervision, Writing - review & editing.

ACKNOWLEDGMENTS

We thank Mr. Ray Tanzer for guidance on ARIMA (autoregressive integrated moving average) methodology, Dr. Michael Reznik for insights on aneurysmal subarachnoid hemorrhage data, and Ms. Krista Mar for insights on data visualization.

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Research (P30AI042853) and by Institutional Development Award Number U54GM115677 from the National Institute of General Medical Sciences of the National Institutes of Health, which funds Advance Clinical and Translational Research (Advance-CTR) from the Rhode Island IDeA-CTR award (U54GM115677).

Received 15 February 2021; accepted 17 April 2021

Citation: *World Neurosurg.* (2021) 151:e523-e532.

<https://doi.org/10.1016/j.wneu.2021.04.080>

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

Available online: www.sciencedirect.com

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Conflict of interest statement: Dr. Wilson is partially supported by the Providence/Boston Center for AIDS