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## Case Volumes and Perioperative Coronavirus Disease 2019 Incidence in Neurosurgical Patients During a Pandemic: Experiences at Two Tertiary Care Centers in Washington, DC

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■ **OBJECTIVE:** The true incidence of perioperative coronavirus disease 2019 (COVID-19) has not been well elucidated in neurosurgical studies. We reviewed the effects of the pandemic on the neurosurgical case volume to study the incidence of COVID-19 in patients undergoing these procedures during the perioperative period and compared the characteristics and outcomes of this group to those of patients without COVID-19.

■ **METHODS:** The neurosurgical and neurointerventional procedures at 2 tertiary care centers during the pandemic were reviewed. The case volume, type, and acuity were compared to those during the same period in 2019. The perioperative COVID-19 tests and results were evaluated to obtain the incidence. The baseline characteristics, including a modified Medically Necessary Time Sensitive (mMeNTS) score, and outcome measures were compared between those with and without COVID-19.

■ **RESULTS:** A total of 405 cases were reviewed, and a significant decrease was found in total spine, cervical spine, lumbar spine, and functional/pain cases. No significant differences were found in the number of cranial or neurointerventional cases. Of the 334 patients tested, 18 (5.4%) had tested positive for COVID-19. Five of these patients were diagnosed postoperatively. The mMeNTS score, complications, and case acuity were significantly different between the patients with and without COVID-19.

■ **CONCLUSION:** A small, but real, risk exists of perioperative COVID-19 in neurosurgical patients, and those

patients have tended to have a greater complication rate. Use of the mMeNTS score might play a role in decision making for scheduling elective cases. Further studies are warranted to develop risk stratification and validate the incidence.

### INTRODUCTION

The coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2, has significantly affected healthcare systems and hospitals worldwide, with >11 million cases and >520,000 deaths confirmed as of July 5, 2020.<sup>1</sup> In line with the preservation of resources and redeployment of the healthcare workforce in the wake of an anticipated surge, the Surgeon General and the American College of Surgeons called for cancellation of elective procedures in mid-March.<sup>2</sup> Specifically, neurosurgical volumes experienced a drastic reduction.<sup>3-6</sup> In an international survey of 494 neurosurgeons, 46.1% reported a >50% decrease in case volumes at the peak of the global pandemic.<sup>4</sup>

Even with a global pandemic, the field of neurosurgery performs some of the most time-sensitive procedures to preserve life and/or function. Even in patients for whom symptoms might not be as overt, operating in a timely fashion can result in better outcomes.<sup>7</sup> Neurosurgical care also requires significant healthcare expenditure and frequent use of intensive care resources. Additionally, the risk of mortality is increased for surgical patients with a COVID-19 diagnosis.<sup>8,9</sup> The increased resource usage and risks of transmission and mortality must be balanced against the benefits of surgery.

#### Key words

- COVID-19
- Neurointerventional
- Neurosurgery
- Pandemic response
- Severe acute respiratory syndrome coronavirus 2

#### Abbreviations and Acronyms

CI: Confidence interval

COVID-19: Coronavirus disease 2019

LOS: Length of stay

mMeNTS: Modified Medically Necessary, Time-Sensitive

OR: Odds ratio

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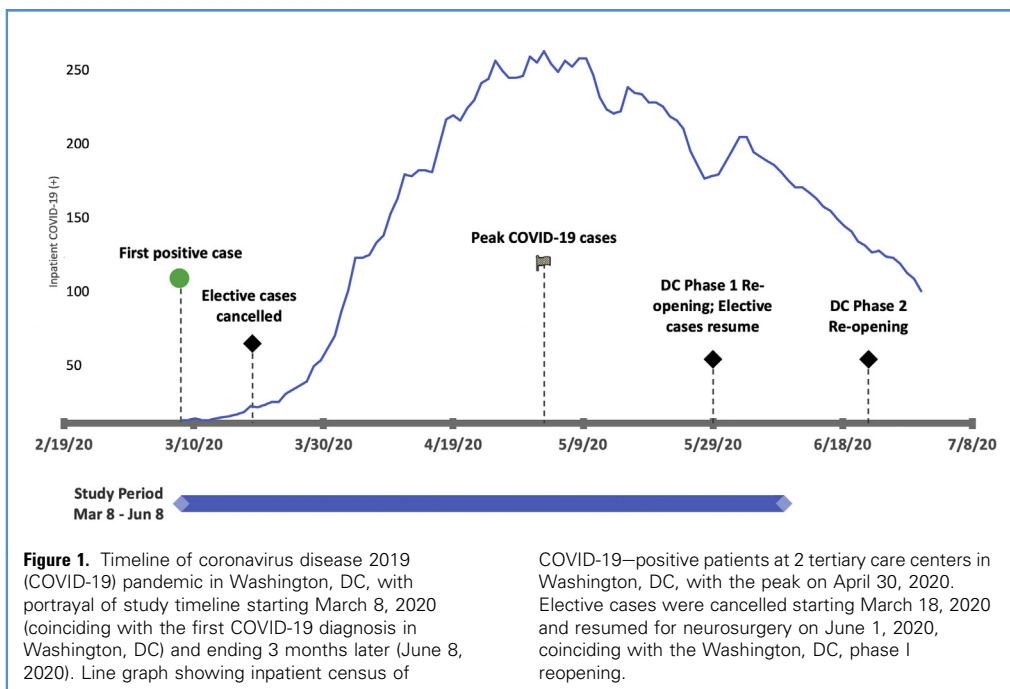
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Several specialty societies have attempted to provide guidance for triaging patients during a resource-restricted timeline.<sup>10-12</sup> Additionally, a slew of editorials regarding individual institutional experiences on management, measures to stop the spread of COVID-19, resource allocation, and service line reorganization have been reported.<sup>13</sup> However, the neurosurgical community has been left to determine the most appropriate course of action from anecdotal experience and paucity of objective data. Specifically, reported data are lacking regarding the perioperative incidence of COVID-19 and the risk of nosocomial spread specific to the neurosurgical population.<sup>14</sup> To the best of our knowledge, only 1 such study has been reported.<sup>15</sup> That study included 55 neurosurgical patients, of whom 4 had tested positive for COVID-19 preoperatively and none postoperatively.<sup>15</sup>

We have described the experience at 2 tertiary care centers in Washington, DC, during the first 3 months of the pandemic and the perioperative incidence of COVID-19 in these patients. We

hypothesized that a true risk of transmission would be found and that patients with COVID-19 would have higher risk profiles and worse outcomes.

**METHODS**

**Study Population**

A retrospective review of all consecutive adult patients who had undergone neurosurgical and neurointerventional procedures under general anesthesia was performed at 2 tertiary care medical centers in Washington, DC (MedStar Georgetown University Hospital and MedStar Washington Hospital Center). The inclusion dates spanned the first 3 months of the pandemic from March 8 to June 8, 2020. March 8 was the first day a positive test was recorded in Washington, DC (Figure 1). Effective March 19 until May 31, 2020, all elective surgeries and procedures were cancelled across both study centers. Data from procedures

**Table 1.** Modified Medically Necessary, Time-Sensitive Procedure Scoring Tool for Scheduling Elective Surgery

Variable	Possible Points		
	1	2	3
Length of stay	Same-day surgery	Observation	>24-Hour stay
Cardiovascular disease	None	1–2 Medications	>2 Medications
Diabetes	No (no medication)	Yes (oral medication)	Yes (insulin dependent)
Lung disease	None	Yes (rescue medications)	Yes (routine medications)
Immunocompromised status	None	1–2 Medications	>2 Medications
Total possible	5	10	15

**Table 2. Baseline Patient Characteristics and Outcomes**

Variable	Surgical	NIR
Total cases ( <i>n</i> )	405	121
Total patients ( <i>n</i> )	386	112
Age (years)	57.1 ± 16.2	61.3 ± 15.4
Sex		
Male	207 (53.6)	65 (58.0)
Female	179 (46.4)	47 (42.0)
Preoperative tests	231 (57.0)	88 (72.7)
Interval from preoperative testing (days)	2.3 ± 3.1	1.5 ± 2.3
Negative result	225 (97.4)	81 (92.0)
Positive result	6 (2.6)	7 (8.0)
Postoperative tests	115 (28.4)	64 (52.9)
Interval to postoperative testing (days)	11.6 ± 10.3	11.1 ± 8.8
Negative result	111 (96.5)	63 (98.4)
Positive result	4 (3.5)	1 (1.6)
Case acuity		
Emergent	92 (22.7)	70 (57.9)
Urgent	183 (45.2)	34 (28.1)
Elective	123 (30.4)	16 (13.2)
Case type		
Spine		NA
Cervical/cervicothoracic	85 (21.0)	
Thoracic	32 (7.9)	
Lumbar/thoracolumbar	105 (25.9)	
Craniotomy		NA
Tumor/abscess	53 (13.0)	
Vascular lesions	25 (6.2)	
ICH/CVA/trauma	32 (7.9)	
Functional/pain	23 (5.7)	NA
CSF diversion	20 (4.9)	NA
Endonasal/transsphenoidal	19 (4.7)	NA
Diagnostic cerebral	NA	39 (32.2)
Embolization	NA	
Aneurysm/AVM		21 (17.4)
Tumor		6 (5.0)
MMA		11 (9.1)
Stroke thrombectomy	NA	29 (24.0)
Vasospasm treatment	NA	6 (5.0)
Spine intervention	NA	8 (6.6)
		Continues

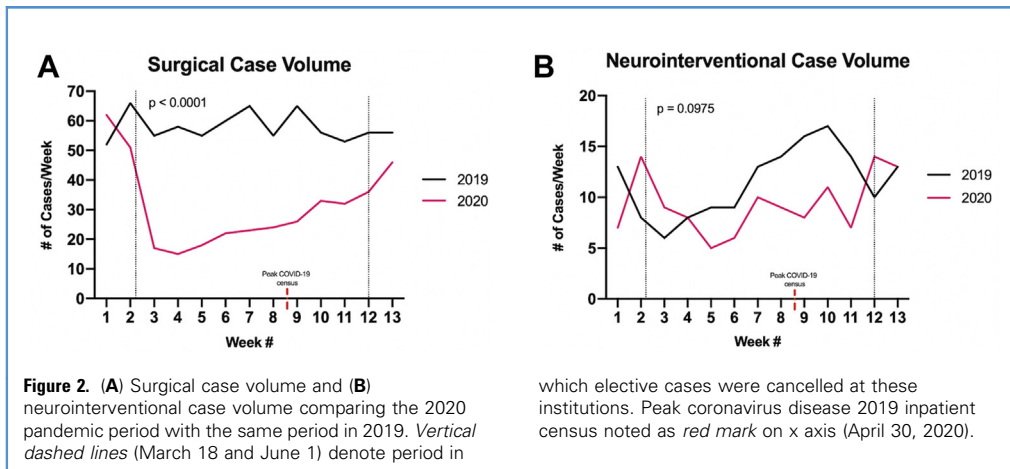
**Table 2. Continued**

Variable	Surgical	NIR
Other	9 (2.2)	1 (0.8)
Race/ethnicity		
White non-Hispanic	203 (52.6)	58 (51.8)
Black/African American	139 (36.0)	45 (40.2)
Hispanic	22 (5.7)	3 (2.7)
Asian	9 (2.3)	2 (1.8)
Other	13 (3.4)	4 (3.6)
Comorbidities		
HTN	190 (49.2)	76 (67.9)
DM	76 (19.7)	26 (23.2)
CAD	28 (7.3)	15 (13.4)
CKD/ESRD	20 (5.2)	12 (10.7)
Malignancy	50 (13.0)	18 (16.1)
COPD	11 (2.8)	8 (7.2)
DVT/PE	20 (5.2)	5 (4.5)
CVA/TIA	25 (6.5)	5 (4.5)
mMeNTS score	8.2 ± 1.6	9.0 ± 1.8
ASA physical status class	2.9 ± 0.7	3.3 ± 0.7
LOS (days)	8.9 ± 11.0	13.5 ± 10.8
Complications	77 (19.0)	58 (47.9)
30-Day readmission	32 (7.9)	7 (5.8)
Disposition at discharge		
Home	285 (70.4)	49 (40.5)
Death/hospice	17 (4.2)	11 (9.1)
Acute rehabilitation	68 (16.8)	48 (39.7)
Skilled nursing facility	27 (6.7)	12 (9.9)
Long-term care facility	8 (2.0)	1 (0.8)
Data presented as <i>n</i> , mean ± standard deviation, or <i>n</i> (%). NIR, neurointerventional radiology; NA, not applicable; ICH, intracranial hemorrhage; CVA, cerebrovascular accident; CSF, cerebrospinal fluid; AVM, arteriovenous malformation; MMA, middle meningeal artery; HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; CKD, chronic kidney disease; ESRD, end-stage renal disease; COPD, chronic obstructive pulmonary disease; DVT, deep venous thrombosis; PE, pulmonary embolism; TIA, transient ischemic attack; mMeNTS, modified Medically Necessary, Time-Sensitive; ASA, American Society of Anesthesiologists; LOS, length of stay.		

during the same period in 2019 were also collected for comparison. The respective institutional review boards at the 2 study centers approved the present study.

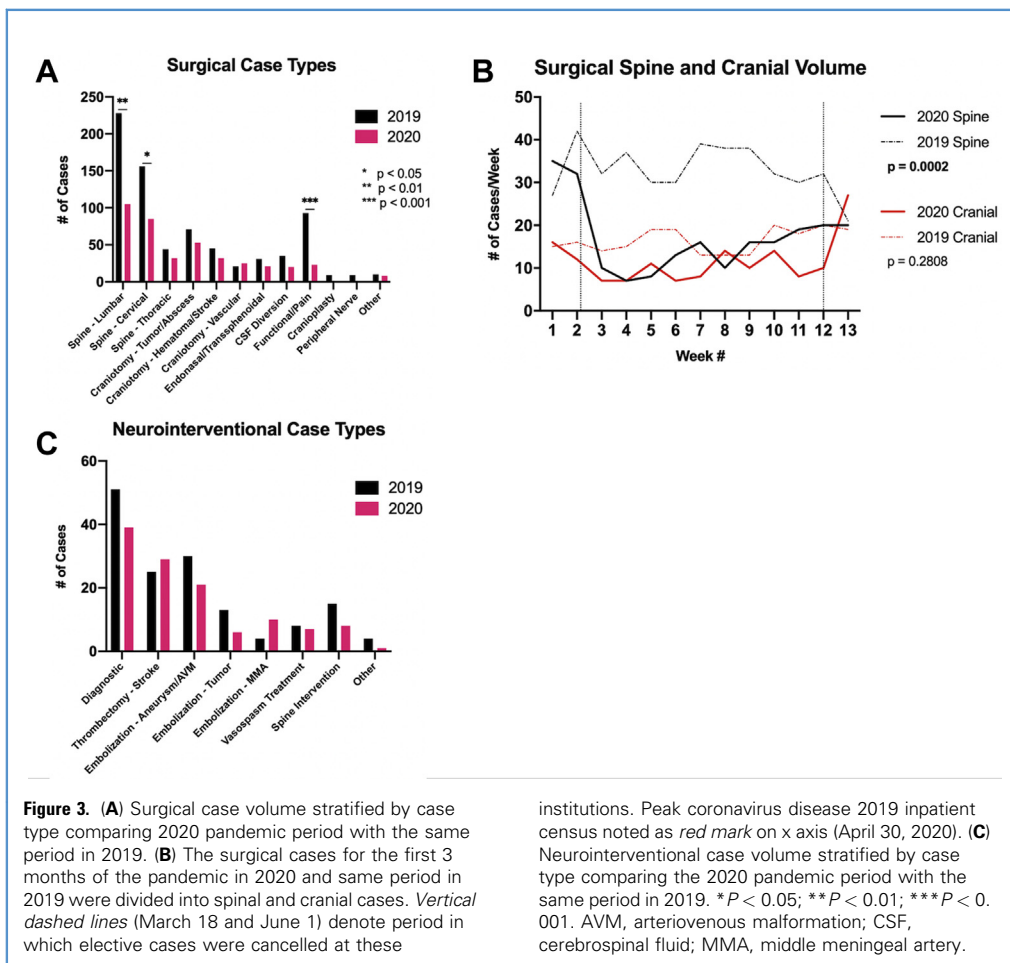
#### Data Collection

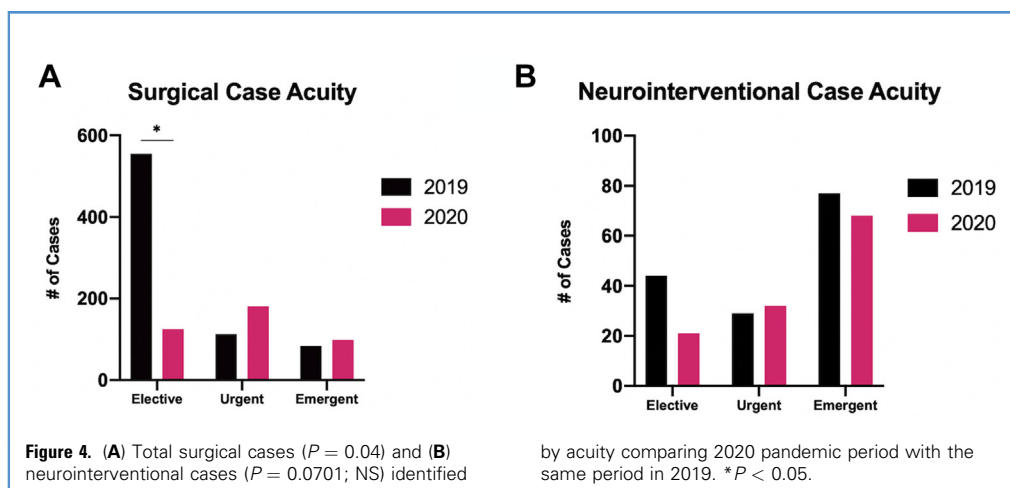
Surgical and neurointerventional cases were categorized by type and acuity. Cases were designated as elective, urgent, or emergent according to the presenting symptoms and neurologic



examination by a blinded reviewer post hoc. Emergent cases were defined as those requiring intervention within 12 hours, urgent cases as those requiring intervention within 1 week, and elective cases as those that could be delayed for  $\geq 2$  weeks.<sup>4</sup>

The patient variables collected included age, sex, race, ethnicity, diagnosis, presenting symptoms, neurologic examination findings, comorbidities, American Society of Anesthesiologists physical status class, postoperative complications, length of stay (LOS),





discharge disposition, 30-day readmission, preoperative COVID-19 status, postoperative COVID-19 status at  $\leq 1$  month, and date of testing. The patient variables between those with and without COVID-19 were compared. Additionally, a simplified and modified Medically Necessary, Time-Sensitive (mMeNTS) score was assigned to all patients by a study member blinded to COVID-19 diagnosis (Table 1). The mMeNTS scoring system was established as a preoperative guide to minimize poor perioperative outcomes and transmission risk for patients requiring operative intervention.<sup>16</sup>

### Statistical Analysis

Continuous variables were summarized as the mean  $\pm$  standard deviation. The *t* test or Wilcoxon rank sum test were used to compare the differences between continuous variables depending on the distribution. Categorical variables were aggregated as frequencies and percentages. The  $\chi^2$  and Fisher exact tests were used to compare the proportional differences in the categorical variables. Logistic regression was used to assess the differences in variables between COVID-19–positive and–negative patients. Multivariable ordinal and logistic regression analysis were used to analyze all independent variables against COVID-19 status. All analyses were performed using Stata, version 16.0 (StataCorp, College Station, Texas, USA). Statistical significance was defined as  $P < 0.05$ .

## RESULTS

### Total Cases

A total of 405 operative neurosurgical cases for 386 patients and 121 neurointerventional cases for 112 patients were performed during the study period (Table 2). In comparison, in 2019, the total was 812 operative neurosurgical cases and 159 neurointerventional cases at the 2 centers. Thus, a 50.1% decrease in the volume of operative cases ( $P < 0.0001$ ) and a 23.9% decrease in neurointerventional cases ( $P = 0.0975$ ) had occurred in the 2020 study period. The largest decrease in case volumes corresponded to the stoppage of elective cases on March 19, 2020 (Figure 2).

### Case Type

Cases classified as lumbar spine, cervical spine, and functional/pain procedures had the most significant decrease in volume (Figure 3). A significant decrease had also occurred in total spine cases ( $P = 0.0002$ ) compared with cranial cases during the pandemic period versus the same period in 2019 ( $P = 0.2808$ ; Figure 3B).

For the neurointerventional cases, no significant decrease occurred in any case category between 2020 and 2019. The largest decline was seen in diagnostic procedures (51 vs. 39). An increase was found in the number of thrombectomy cases (25 vs. 29) and middle meningeal artery embolization cases (4 vs. 10). However, the differences were not statistically significant (Figure 3C).

When categorized by acuity, a significant decrease had occurred in elective cases ( $P < 0.0001$ ), with no significant change in the number of urgent or emergent cases in the surgical category. In the neurointerventional category, no significant changes were found in the number of elective, urgent, or emergent cases, although the elective procedures had decreased by 52.3% (Figure 4).

### COVID-19 Incidence

A total of 319 patients (64.1%) had undergone preoperative testing for COVID-19 (231 surgical; 88 neurointerventional). Of these patients, 6 (2.6%) in the surgical group and 7 (8.0%) in the neurointerventional group had tested positive for COVID-19 preoperatively. Of these 13 patients, 10 had tested positive within 1 day of surgery. The other 3 had tested positive an average of 11 days before surgery. It was determined that their surgery could be postponed, and they were retested immediately before surgery with negative results. Postoperatively, 179 tests were administered (115 surgical; 64 neurointerventional). Of these, 4 patients (3.5%) tested positive in the surgical group (3.5%) and 1 tested positive in the neurointerventional group (1.6%) within 30 days after their procedure (Table 2). All patients who tested positive postoperatively had tested negative preoperatively. The criteria for postoperative testing included clinical suspicion, an upcoming procedure, and placement to another facility.

**Table 3.** Summary of Patients with Coronavirus Disease 2019

Diagnosis Date	ASA Score	mMeNTS Score	Primary Diagnosis	Procedure	Complication	LOS (days)	Disposition at Discharge
Preop							
4/17	3	9	Cervical cord compression	C3-C7 posterior laminectomy; C3-T1 instrumented fusion	Bacteremia; transaminitis	28	AR
4/20	2	9	Left MCA occlusion	Left MCA mechanical thrombectomy	None	5	AR
4/24	4	9	SAH (HH score, 2)	Diagnostic angiogram	None	3	Home
4/24	3	10	Right MCA occlusion	Right MCA mechanical thrombectomy	Malignant cerebral edema	3	Death
4/28	3	9	Left skull base/orbital sarcoma	Endonasal endoscopic resection of anterior skull base tumor	None	17	Home
5/2	4	12	SAH/intraventricular hemorrhage	Diagnostic angiogram	AKI; femoral pseudoaneurysm	12	AR
5/4	3	12	Right ICA occlusion	Right ICA mechanical thrombectomy	None	8	AR
5/6	3	12	Right MCA occlusion	Right decompressive hemicraniectomy	Malignant cerebral edema; extremity gangrene	33	Death
5/7	4	8	C4 vertebral body fracture	C4 corpectomy; C5-C6 anterior cervical discectomy; fusion	DVT	25	AR
5/13	4	9	Right MCA occlusion	Right MCA mechanical thrombectomy	None	3	AR
5/13	3	12	Thoracic cord compression	T10-T11 laminectomy/T8–L2 posterior instrumented fusion	Hematuria	7	AR
5/27	3	9	Cauda equina syndrome	L3–S1 laminectomy; L3-L4 microdiscectomy	STEMI	17	Home
5/31	3	8	SAH/aneurysm rupture (HH score, 2)	Endovascular coiling of bilateral Pcom artery aneurysms	MSSA PNA	22	AR
Overall	3.2 ± 0.6	9.8 ± 1.6	NA	NA	8/13	14.1 ± 10.3	NA
Postop							
4/11	3	10	Cervical myelopathy	C3–C6 posterior laminectomy; instrumented fusion	AKI; UTI; DVT	16	SNF
4/19	4	8	Left intraparenchymal hemorrhage (ICH score, 2)	Diagnostic angiogram	Sepsis; cholelithiasis	18	AR
5/28	4	9	Bifrontal traumatic contusions	Bilateral decompressive hemicraniectomy	Atrial fibrillation with RVR	20	AR
6/16	4	11	SAH/IPH (HH score, 3)	Diagnostic angiogram/left decompressive hemicraniectomy	MSSA PNA; fungemia; <i>Clostridium difficile</i>	28	SNF
6/17	4	11	SAH/aneurysm rupture (HH score, 4)	Endovascular coiling of Acom artery aneurysm/right craniotomy for hematoma evacuation	Status epilepticus; UTI	28	LTC
Overall	3.8 ± 0.4	9.8 ± 1.3	NA	NA	5/5	22.0 ± 5.6	NA

Data presented as *n/N* or mean ± standard deviation.

ASA, American Society Anesthesiologists; mMeNTS, modified Medically Necessary, Time-Sensitive; LOS, length of stay; Preop, preoperatively; AR, acute rehabilitation; MCA, middle cerebral artery; SAH, subarachnoid hemorrhage; HH, Hunt-Hess (classification); AKI, acute kidney injury; ICA, internal cerebral artery; DVT, deep venous thrombosis; STEMI, ST elevation myocardial infarction; Pcom, posterior communicating artery; MSSA: methicillin-sensitive *Staphylococcus aureus*; PNA, pneumonia; NA, not applicable; Postop, postoperatively; UTI, urinary tract infection; ICH, intracranial hemorrhage; RVR, rapid ventricular rate; IPH, intraparenchymal hemorrhage; SNF, skilled nursing facility; Acom, anterior communicating artery; LTC, long-term care.

### COVID-19—Positive Patients

Of the 334 patients who had been tested in the perioperative period, 18 (5.4%) had tested positive and 316 (94.6%) had tested

negative (Table 3). Of the 18 patients, 13 (13 of 319 tested preoperatively for a 4.1% positive test rate) had tested positive preoperatively and 5 (5 of 180 tested postoperative, for a 2.8%

**Table 4.** Differences Stratified by Coronavirus Disease 2019 Status

Variable	COVID-19		P Value
	Yes	No	
Total cases	18	338	
Total patients	18	316	
Case category			0.0974
Surgical	10 (55.5)	252 (74.6)	
Neurointerventional	8 (44.5)	86 (25.4)	
Age (years)	55.3 ± 14.5	58.0 ± 16.0	0.4690
Sex			0.4184
Male	9 (50.0)	187 (59.2)	
Female	9 (50.0)	129 (40.8)	
Positive preoperatively	13 (72.2)	NA	NA
Positive postoperatively	5 (27.8)	NA	NA
Total negative preoperatively	NA	167 (90.2)	NA
Total negative postoperatively	NA	149 (47.2)	NA
Case acuity			0.0001*
Emergent	15 (83.3)	117 (34.6)	
Urgent	3 (16.7)	148 (43.8)	
Elective	0 (0.0)	73 (21.6)	
Case type			0.0876
Spine			
Cervical/cervicothoracic	3 (16.7)	40 (11.8)	
Thoracic	1 (5.6)	26 (7.7)	
Lumbar/thoracolumbar	1 (5.6)	60 (17.8)	
Craniotomy			
Tumor/abscess	0 (0.0)	40 (11.8)	
Vascular lesions	1 (5.6)	15 (4.4)	
ICH/stroke/trauma	3 (16.7)	21 (6.2)	
Functional/pain	0 (0.0)	14 (4.1)	
CSF diversion	0 (0.0)	14 (4.1)	
Endonasal/transsphenoidal	1 (5.6)	18 (5.3)	
Diagnostic cerebral	0 (0.0)	28 (8.3)	
Embolization			
Aneurysm/AVM	0 (0.0)	8 (2.4)	
Tumor	0 (0.0)	5 (1.5)	
MMA	0 (0.0)	8 (2.4)	
Stroke thrombectomy	0 (0.0)	22 (6.5)	
Vasospasm treatment	0 (0.0)	6 (1.8)	
Spine intervention	0 (0.0)	8 (2.4)	

Continues

**Table 4.** Continued

Variable	COVID-19		P Value
	Yes	No	
Other	0 (0.0)	5 (1.5)	
Race/ethnicity			0.0059*
White	4 (22.2)	162 (51.3)	
African-American	8 (44.4)	122 (38.6)	
Hispanic	5 (27.8)	13 (4.1)	
Asian	1 (5.6)	7 (2.2)	
Other	0 (0.0)	12 (3.8)	
Comorbidities			0.5793
HTN	12 (66.7)	174 (55.1)	
DM	6 (33.3)	60 (19.0)	
CAD	2 (11.1)	31 (9.8)	
CKD/ESRD	4 (22.2)	16 (5.1)	
Malignancy	3 (16.7)	59 (18.7)	
COPD/asthma	1 (5.6)	20 (6.3)	
DVT/PE	2 (11.1)	16 (5.1)	
CVA/TIA	1 (5.6)	17 (5.4)	
Obesity	6 (33.3)	61 (19.3)	
mMeNTS score	9.8 ± 1.5	8.4 ± 1.7	0.0013*
LOS (days)	16.2 ± 9.8	10.5 ± 11.1	0.0316*
ASA physical status score	3.4 ± 0.6	3.1 (0.7)	0.0827
Complications	13 (72.2)	82 (24.3)	<0.0001*
30-Day readmission	1 (5.6)	32 (9.5)	0.5658
Disposition at discharge			0.0009*
Home	3 (16.7)	199 (63.0)	
Death/hospice	2 (11.1)	18 (5.7)	
Acute rehabilitation	10 (55.6)	68 (21.5)	
Skilled nursing facility	2 (11.1)	23 (7.3)	
Long-term care facility	1 (5.6)	8 (2.5)	

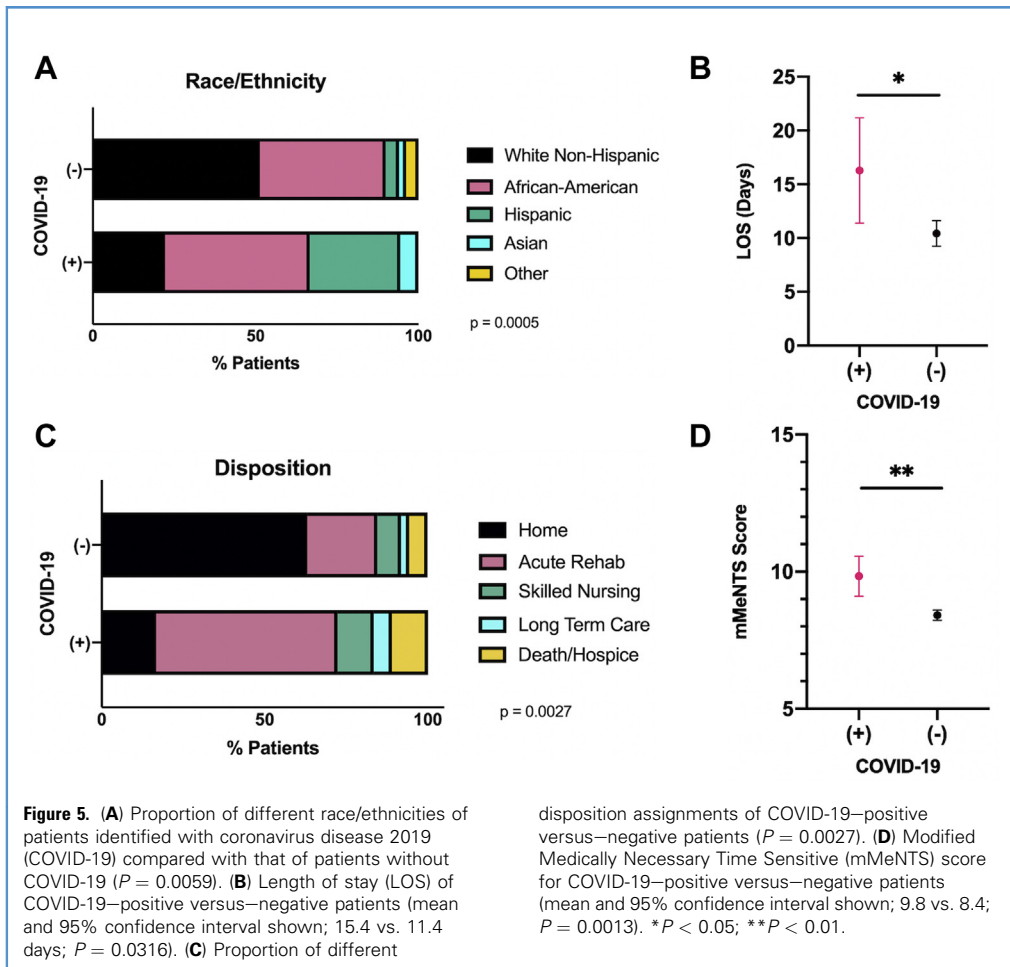
Data presented as *n*, *n* (%), or mean ± standard deviation.

COVID-19, coronavirus disease 2019; NA, not applicable; ICH, intracranial hemorrhage; CSF, cerebrospinal fluid; AVM, arteriovenous malformation; MMA, middle meningeal artery; HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; CKD, chronic kidney disease; ESRD, end-stage renal disease; COPD, chronic obstructive pulmonary disease; DVT, deep venous thrombosis; PE, pulmonary embolism; CVA, cerebrovascular accident; TIA, transient ischemic attack; mMeNTS, modified Medically Necessary, Time-Sensitive; LOS, length of stay; ASA, American Society of Anesthesiologists.

\*Statistically significant.

positive test rate) had tested positive postoperatively (Table 4). All 18 patients had undergone urgent or emergent procedures. The overall case acuity was significantly greater for the COVID-19–positive patients ( $P < 0.0001$ ).





A significant difference was found in the race and/or ethnicity of the patients testing positive, with significantly more patients identifying as Hispanic and African American in the positive group (odds ratio [OR], 3.68; 95% confidence interval [CI], 1.25–10.43;  $P = 0.0266$ ; **Figure 5**). The mean mMeNTS score was significantly

greater for the COVID-19–positive patients than for those with negative test results (9.8 vs. 8.4;  $P = 0.0013$ ; **Figure 5D**). Compared with the COVID-19–negative patients, those with positive test results also had had an increased LOS by almost 6 days (16.2 vs. 10.5;  $P = 0.0316$ ; **Figure 5B**) and were more likely to develop an in-hospital complication other than the COVID-19 diagnosis (OR, 7.42; 95% CI, 2.66–19.22;  $P < 0.0001$ ). Additionally, a significant difference was found in the overall disposition for the COVID-19–positive patients ( $P = 0.0009$ ), with fewer going home compared with those with negative test results (16.7% vs. 58.9%;  $P = 0.0027$ ; **Figure 5C**). Two patients (11.1%) who had tested positive died in-hospital. Both had had large vessel occlusions (**Table 3**). All other COVID-19–positive patients who survived hospitalization were alive at the 30-day follow-up from the index case.

Case acuity, the occurrence of inpatient complications, and the mMeNTS score remained significantly different between the 2 groups on multivariate analysis controlling for confounding variables (**Table 5**). Of the 5 patients with a postoperative diagnosis of COVID-19, all had been diagnosed  $\geq 8$  days after surgery (mean, 13.3 days), had had a mMeNTS score of  $\geq 9$  (mean, 10.0), had developed inpatient complications, and had been discharged to locations other than home (**Table 3**).

**Table 5. Significant Variables on Multivariate Ordinal Regression Stratified by Coronavirus Disease 2019 Status**

Variable*	OR	95% CI	P Value
mMeNTS	2.03	1.13–3.86	0.0226†
Case acuity	5.24	1.65–24.4	0.0133†
Complications	7.53	1.76–39.1	0.0099†

OR, odds ratio; CI, confidence interval; mMeNTS, modified Medically Necessary, Time-Sensitive.

\*Age, sex, ethnicity/race, comorbidities, American Society of Anesthesiologists physical status, procedure type, length of stay, disposition, and readmission were also adjusted for on multivariate analysis, but the differences were not statistically significant ( $P < 0.05$ ).

†Statistically significant.

## DISCUSSION

In the present 2-center study, a decrease was found in the total case volumes, elective cases, and spine and functional/pain procedures, with no appreciable decrease in neurointerventional cases. The incidence of perioperative COVID-19 in the neurosurgical population was 5.4%, with, specifically, a 2.8% positive test rate after a confirmed negative preoperative test (i.e., hospital-acquired COVID-19). The incidence of a perioperative diagnosis of COVID-19 in the neurosurgical population is an important consideration given the increased complications, increased LOS, and greater risk profiles observed for these patients.

### Case Volumes in Neurosurgery

The reduction in case volume was not surprising given the halt of elective cases and has been reported by others.<sup>3,17</sup> The larger decrease in spine cases also resulted because of their mostly elective nature.<sup>3</sup> Cranial procedures also showed a decrease, although the difference was not significant. In Ancona, Italy, neuro-oncologic cases and the proportion of acute neuro-oncologic cases also increased, with 57.1% of tumor cases defined as emergent compared with 31.1% in the same months in 2019. This was attributed to patient concerns regarding exposure from hospitalization and difficulty in accessing radiologic examinations, resulting in more acute presentations.<sup>18</sup> Their findings are consistent with those from our study, demonstrating an increase from 53.5% to 89.8% in nonelective cranial neuro-oncology cases from 2019 to 2020.

However, the overall number of neurointerventional cases did not decrease significantly. This could have resulted from the selection of cases specifically for general anesthesia and the relatively acute nature of these procedures. Fiehler et al.<sup>19</sup> reported the results from an international survey, demonstrating a significant decrease in emergent neurointerventional volume reported by 60% of the responders. We did not find such a decrease in our study. Although a decrease had occurred in nonelective neurointerventional cases, the difference was not significant. This could have resulted from the acquisition of new referring community hospitals since 2019, increasing the overall volume. Similarly, Sweid et al.<sup>20</sup> reported an increase in thrombectomies at their institution in Philadelphia despite an overall decrease in acute stroke admissions.

### COVID-19–Positive Patients

The total census of COVID-19–positive patients at both institutions peaked at 268 on April 30, 2020 and averaged >220 for  $\geq 2$  weeks before and after the peak (Figure 1). The average LOS for COVID-19–positive patients at the 2 centers was 10.79 days, with a 15.3% mortality rate for inpatients. However, for our COVID-19 cohort, the average LOS was 16.2 days, with an 11.1% mortality rate. The increased LOS could have been because of the overall increased care that neurosurgical patients require. The lower mortality rate could have been from a selection bias, because only operative patients were studied, excluding patients who were too critically ill.

It is well established that people of ethnic and minority populations have a disproportionately increased risk of acquiring COVID-19 and experience poorer outcomes, irrespective of

age.<sup>21–23</sup> Similarly, our study showed more positive cases in ethnic and minority patients compared with non-Hispanic white patients. We found an almost 30% increase in the proportion of black and Hispanic patients in the COVID-19–positive group compared with the negative group (Figure 5A and Table 4). These findings are comparable to other data from Washington, DC, with 37% of positive patients identifying as black and 28% as Hispanic or Latino, despite constituting only 11.3% of the total city population.<sup>24</sup>

### Nosocomial Infection Rate

Although the nosocomial transmission of COVID-19 presents an obvious risk for patients admitted during the peak pandemic period, this risk has not been well defined in the current data. Several studies have investigated the transmission of COVID-19 to healthcare workers, with rates ranging from 1.1% to 11.6% reported.<sup>25–27</sup> We found a 2.8% positive COVID-19 rate among our patients who had had a negative test before their procedure. As expected, this rate was lower than most of the nosocomial transmission rates to healthcare workers that have been reported in previous studies.<sup>25–27</sup> In contrast, the risk of any nosocomial infection among patients admitted to a neurosurgical intensive care unit before the COVID-19 pandemic was estimated at 3.7%–5%.<sup>28</sup> Therefore, the risk of COVID-19 transmission during this period represents a 40%–50% increase in the risk of all nosocomial infections to this patient population.

The average LOS for the patients with nosocomial transmission of COVID-19 was also markedly longer at 21.6 days compared with 10.5 days for the patients without COVID-19 during their hospital stay ( $P = 0.0219$ ). Additionally, the group with nosocomial transmission had been diagnosed further out from surgery although the difference was not significant (13.3 vs. 11.5 days postoperatively). Moreover, all 5 patients who had tested positive postoperatively had experienced major in-hospital complications, in addition to the COVID-19 diagnosis. These data highlight the added risk to patients who had undergone neurosurgical or neurointerventional procedures in the setting of the COVID-19 pandemic.

No COVID-19 transmissions were observed among the neurosurgical residents, advanced care practitioners, or attendings at the 2 centers. However, the risk to providers remains a concern, with 3387 confirmed cases among medical professionals in 476 healthcare organization worldwide recorded in March.<sup>29</sup>

### Risk Stratification and Strategies

Since June 1, 2020, elective neurosurgical cases have resumed at the study centers. Using the mMeNTS tool, each case is scored by the surgeon at the time of posting (Table 1). Cases for patients with a score >10 are advised to be postponed. All patients are tested for COVID-19 within 5 days before surgery. If a patient tests positive, the surgery is delayed for 1 month and the patient is retested. If the surgeon needs to proceed with the case before then, the case proceeds under the COVID-19 precautions. If the procedure is considered at high risk for generating aerosols (e.g., endonasal cases), COVID-19 precautions are required regardless of the COVID status of the patient. The need for an intensive care unit bed postoperatively, blood transfusions, and rehabilitation

placement after hospitalization are also considered. These factors are a part of an overall algorithm specific to neurosurgical patients and similar to that discussed by Burke et al.<sup>30</sup>

Although established as a preoperative scoring system,<sup>16</sup> the mMeNTS score was applied post hoc to our study population. The score for patients requiring intervention during the pandemic was  $8.4 \pm 1.7$ , well below the cutoff of 10 used for posting elective cases. Nonetheless, a significant difference was found in the mMeNTS scores between the COVID-19–positive and–negative patients on multivariate analysis (9.8 vs. 8.4; OR, 2.03; 95% CI, 1.13–3.86;  $P = 0.0226$ ). Thus, the mMeNTS score allows for quick risk stratification for scheduling cases and could be beneficial if incorporated into practice during this pandemic.

### Study Limitations

We performed a retrospective analysis of COVID-19 incidence during the pandemic period. Our findings might not be generalizable to other institutions or regions that could have had a different experience with the pandemic and different methods for managing the

outbreak. Although blinded independent reviewers the assigned acuity and mMeNTS scores in our cohort, the post hoc assignments could have been biased, and the full circumstances surrounding a case might not have been available. Further prospective and multiregional studies with increased sample sizes are warranted to provide a more representative view of perioperative COVID-19 incidence and risk in the neurosurgical population.

### CONCLUSION

The rate of COVID-19 infection in patients requiring neurosurgical intervention during the pandemic has been low but should be considered when scheduling cases. As testing becomes more prevalent, further multi-institutional studies are needed to truly determine the incidence of COVID-19 and its impact on how and when surgeries are performed. To maximize the safety of providers and patients, precautions will be required for the foreseeable future as elective cases increase in quantity.

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