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Impact of the COVID-19 Pandemic on Neurosurgical Practice at an Academic Tertiary Referral Center: A Comparative Study

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■ **BACKGROUND:** Neurosurgical services have been affected by the 2019 novel coronavirus disease (COVID-19) pandemic, and several departments have reported their experiences and responses to the COVID-19 crisis in an attempt to provide insights from which other impacted departments can benefit. The goals of this study were to report the load and variety of emergent/urgent neurosurgical cases after implementing the “Battle Plan” at an academic tertiary referral center during the COVID-19 pandemic and to compare these variables with previous practice at the same institution.

■ **METHODS:** The clinical data of all patients who underwent a neurosurgical intervention between March 23, 2020, and April 20, 2020, were obtained from a prospectively maintained database. Data of the control group were retrospectively collected from the medical records to compare the types of surgeries/interventions performed by the same neurosurgical service before the COVID-19 pandemic started.

■ **RESULTS:** Over a 4-week period during the COVID-19 pandemic, 91 patients underwent emergent, urgent, and essential neurosurgical interventions. Patient screening at teleclinics identified 11 urgent surgical cases. The implementation of the Battle Plan led to a significant decrease in the caseload, and the variation of cases by subspecialty was evident when compared with a control group comprising 214 patients.

■ **CONCLUSIONS:** Delivery of optimal care and safe practice and education at an academic neurosurgical

department can be well maintained with proper execution of crisis protocols. Teleclinics proved to be efficient in screening patients for urgent neurosurgical conditions, but in-person clinic visits may still be necessary for some cases in the immediate postoperative period.

INTRODUCTION

The 2019 novel coronavirus disease (COVID-19) has taken a heavy toll on various aspects of society. In pandemic regions, health care systems are being shaped by the numbers of patients with COVID-19 requiring urgent medical attention.¹ Hospitals are improvising and continuously revising protocols to maintain an efficient level of functioning amidst significant shortages in facilities and equipment.²⁻⁴

Neurosurgical services, albeit not directly concerned with managing COVID-19 complications, are affected by the pandemic owing to the precautionary need to preserve resources. Several departments have reported their experiences and responses to the COVID-19 crisis in an attempt to provide insights from which other impacted departments can benefit.⁵⁻⁹ We recently published our response, the “Battle Plan,” at the University of South Florida Department of Neurosurgery,¹⁰ which has so far been successful in sustaining optimal management of patients with urgent/emergent neurosurgical conditions and a safe environment for all personnel involved in the care of these patients. The goals of this study are to report the load and variety of emergent/urgent neurosurgical cases after implementing the Battle Plan¹⁰ at an academic tertiary

Key words

- Battle Plan
- Caseload
- Case variety
- COVID-19
- Neurosurgical practice
- Pandemic

Abbreviations and Acronyms

COVID-19: 2019 novel coronavirus disease

ED: Emergency department

OR: Operating room

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referral center during the COVID-19 pandemic and to compare these variables with previous practice at the same institution.

MATERIALS AND METHODS

Patient Population and Study Design

The clinical data of all patients who underwent a neurosurgical intervention between March 23, 2020, and April 20, 2020, were obtained from a prospectively maintained database at a Level I trauma center, to which adult and pediatric patients are transported from 23 surrounding counties. The academic center at which the study was conducted houses >1000 beds, and the neurosurgical service is covered by 12 full-time neurosurgeons with variable expertise in various neurosurgical subspecialties (spinal surgery, skull base surgery, neuro-oncology, traumatology, neurovascular surgery, functional surgery, pediatric neurosurgery). Only interventions that were deemed necessary to save a patient's life or preclude neurologic deterioration were carried out during the pandemic,¹⁰ the urgency of which was classified as follows: emergent, requiring immediate transfer to the operating room (OR) (e.g., head/spinal cord trauma, cauda equina syndrome, acute hydrocephalus); urgent—within 1 day (i.e., urgent) (e.g., brain tumors with mass effect, progressive spinal cord myelopathy) or urgent—within 1 week (i.e., essential) (e.g., carotid endarterectomy following a middle cerebral artery stroke; cord decompression and cervical spine fusion following trauma leading to central cord syndrome), where the intervention should be performed within 1 day or within 1 week, respectively, to preserve neurologic function.

Per the Battle Plan protocols,¹⁰ inpatients as well as new neurosurgical patients were presented in a daily 6 AM meeting of the covering team, and the new cases were scheduled per rank of urgency. Emergent cases presenting to the emergency department (ED) were admitted per judgment of the attending physicians on-call and prepared for surgery without any delay in management. The Battle Plan also required that all urgent and essential cases be intubated in a negative-pressure operative suite separate from the OR with anesthesia personnel in full PPE to protect the team and to diminish the chance of in-hospital “community spread” of COVID-19. Emergent cases were usually already intubated in-transfer or in the ED, potentially placing first responders at risk of exposure. Other aspects of the Battle Plan included minimizing face-to-face contact between different teams, followed by 2 weeks off-service in relative social isolation after a week of service, which was consistent with the Centers for Disease Control and Prevention quarantine recommendations to prevent potential spread of COVID-19 among all personnel of the neurosurgery department.¹⁰ Key elements of the Battle Plan are summarized in **Table 1**.

Data of the control group comprising patients who underwent neurosurgical interventions over a 6-month period (January 1, 2019 to June 30, 2019) were retrospectively collected from the medical records to compare the types of surgeries/interventions performed by the same neurosurgical service before the COVID-19 pandemic started; the 6-month data of regular practice was averaged to 4 weeks for the purpose of comparison with the 4-week data collected after implementing the Battle Plan.¹⁰ The institutional review board approved the study protocol (STUDY000784).

Obtaining patient consent was waived by the institutional review board owing to the retrospective nature of the study.

RESULTS

The demographic and clinical data of 91 patients who underwent neurosurgical interventions over 4 weeks after implementing the Battle Plan¹⁰ during the COVID-19 pandemic are summarized in **Table 2**. All patients were admitted through the ED; the initial evaluation of most of the patients (72.5%) was performed in the ED, whereas direct referral from teleclinic and transfer from another institution accounted for 12.1% and 11% of the patient population, respectively. Four (4.4%) patients underwent an intervention after an in-hospital consultation. The neurosurgical interventions comprised 57 (62.6%) open surgeries requiring an OR and 34 (37.4%) endovascular procedures requiring an angiography suite. Seventeen (18.7%) patients required an emergent intervention, and 65 (71.4%) required an urgent intervention within 24 hours. Nine (9.9%) patients were categorized as essential, who were in need of surgery within 1 week but able to be delayed by a few days or even in some cases benefited from a delay of several days (e.g., carotid endarterectomy following a middle cerebral artery stroke; cord decompression and cervical spine fusion following trauma leading to central cord syndrome). The median age at surgery was 58 years (range, 4–84 years). The median operative time was 2.12 hours in 57 patients who underwent any type of open surgery (other than endovascular procedures), and the median length of hospital stay was 5 days in 77 patients who were discharged; 14 (15.4%) patients were still in the hospital by the time data collection was concluded. Of patients, 50.6% were discharged home, and 19.7% were discharged to an inpatient rehabilitation center. The mortality rate was 7.7%.

The control group comprised 214 surgical cases (per 4 weeks; averaged from 6 months of data) performed during regular practice. Comparison of the numbers and relative percentages of neurosurgical interventions by patient population (adult vs. pediatric) and subspecialty (craniotomy/biopsy for brain tumor, trauma or pain; open vascular; endoscopic endonasal; functional and epilepsy; ventriculoperitoneal shunt; peripheral nerve; spine; and endovascular) between regular practice and practice after implementing the Battle Plan¹⁰ during the COVID-19 pandemic are reported in **Figure 1**. Endovascular and adult spine procedures were consistently the first and second most common subspecialty procedures during the periods before COVID-19 and during COVID-19 epochs, whereas adult functional/epilepsy (18.1%) and adult craniotomy/biopsy for brain tumor (11%) switched positions, with adult functional/epilepsy occupying third place before COVID-19 and adult craniotomy/biopsy for brain tumor occupying third place during COVID-19.

DISCUSSION

The impact of the COVID-19 pandemic on different aspects of the neurosurgical service at our main academic center was similar to experiences reported at other institutions.^{6–9} Crucial practice modifications, collectively referred to as the Battle Plan,¹⁰ involved in-hospital service coverage, surgical staffing, clinic evaluations, and educational and research activities (**Table 2**). Although the shelter-in-place order was not officially implemented in Florida

Table 1. Key Elements of the Battle Plan¹⁰

Battle Plan teams	Service personnel are divided into 3 teams; each team is composed of 3 attending physicians (1 cranial/open vascular, 1 spinal, 1 endovascular), 1 chief resident, and 3 junior residents
	Each team covers the service for 1 week, followed by 2-week home quarantine per CDC recommendations
	Any physical meeting between members of 2 different teams, whether inside or outside the hospital premises, is strictly prohibited
	COVID-19 testing of team members is reserved for individuals displaying signs/symptoms
	Transfer of care occurs in 2 phases (Sunday afternoon and Monday morning) through videoconferencing to avoid contact between incoming and outgoing teams
Surgical staffing	All elective neurosurgical cases are canceled
	New patients with urgent conditions are presented during the daily 6 AM meeting and scheduled according to rank of urgency
	Emergent cases are admitted through the ED and staffed for surgery per judgment of the attending physician on call
Safety	Proper PPE is provided to personnel examining new patients in the ED as well as consultants who are either COVID-19–positive or of indeterminate status
	All hospital personnel wear surgical masks to avoid in-hospital community spread
	All scheduled cases undergo COVID-19 testing regardless of presence/absence of disease manifestations
	Patients are intubated/extubated in a designated negative-pressure OR, with anesthesia team in full PPE
Teleclinic	All new and most follow-up clinic visits are conducted through telemedicine by faculty of the teams that are quarantined at home
	Patients are screened for urgent/emergent conditions before setting an appointment
	Patients requiring urgent (but not emergent) in-person evaluation are directed to the APP clinic service, which is also on rotation, and subsequently seen by the covering attending physicians as necessary
	Postoperative visits are also conducted through telemedicine, unless in-person visits are necessary
	Only the patient is allowed into the clinic during the in-person visit, although guests are welcomed into a telemedicine format
Education/research activities	Grand rounds, journal clubs, and all other conferences are organized through videoconference applications, and attendance of all Battle Plan teams members remains mandatory
	Residents continue to conduct their research remotely (e.g., chart reviews, manuscript write-up)
	The 2-week home quarantine is an excellent opportunity for residents to read neurosurgical references and prepare for board examinations
CDC, Centers for Disease Control and Prevention; COVID-19, 2019 novel coronavirus disease; ED, emergency department; PPE, personal protective equipment; OR, operating room; APP, advanced practice provider.	

until April 2, March 23 was chosen as the starting date for the implementation of Battle Plan at our department owing to a sharp rise in the number of COVID-19 cases in our community in the prior week; this also coincided with the issuance of Centers for Disease Control and Prevention recommendations in the second week of March.

As expected, these modifications affected the neurosurgical caseload and variety as shown in **Figure 1**. The total number of cases decreased by more than half (214 vs. 91 over a 4-week period), which was a direct consequence of the rigid stratification of possible neurosurgical interventions into specific categories of emergent, urgent, and essential. Cases were stratified first by the neurosurgery service and then submitted for review to a multidisciplinary OR Governance Committee to ensure proper selection and equitable distribution of OR time and space. Only emergent, urgent, and essential cases were admitted and scheduled for surgery; the majority of these cases presented to the ED directly. Teleclinic patient screening by the Battle Plan teams who were in social isolation was surprisingly efficient in

identifying urgent and essential cases (11 patients: 10 requiring an intervention within 1 day and 1 requiring an intervention within 1 week). We predict that telemedicine will be heavily incorporated into neurosurgical practice after the pandemic ends, especially as most personnel at academic centers have acquired experience in evaluating patients in the telemedicine format nearly as effectively as during in-person clinic visits. Several limitations still exist, especially those related to obtaining imaging studies performed at institutions/radiology centers outside of our hospital system and workflow related to incorporating residents, fellows, and advanced practice providers in the telemedicine visits for purposes of education and efficient clinical practice. Rapid and efficient cross-institutional sharing of imaging studies will be resolved in the era of high-speed Internet, where remote access to these imaging studies can be granted to providers.¹⁰ Workflow issues will require redefining the roles, duties, and job descriptions of the nonfaculty providers. Only 17 of the 91 cases were classified as emergent, including strokes, ruptured aneurysms, and hematoma evacuations,

Table 2. Demographic and Clinical Data of Patients Who Underwent a Neurosurgical Intervention over a 4-Week Period After Implementing the Battle Plan¹⁰ at an academic Tertiary Referral Center

	Number (%)
Sex	
Female	37 (40.7)
Male	54 (59.3)
Medium of presentation	
ED	66 (72.5)
Clinic referral	11 (12.1)
Transfer from another institution	10 (11)
In-hospital consultation	4 (4.4)
Classification of neurosurgical intervention	
Emergent	17 (18.7)
Urgent	65 (71.4)
Essential	9 (9.9)
Discharge disposition	
Home	46 (50.6)
Rehabilitation inpatient	18 (19.7)
Hospital inpatient	14 (15.4)
SNF	4 (4.4)
Psychiatry inpatient	1 (1.1)
LTAC	1 (1.1)
Deceased	7 (7.7)
Median (IQR; Range)/Mean (SD)	
Age at surgery, years	58 (39–65; 4–84)/52.9 (19.3)
Operative time, hours*	2.12 (1.2–3.47; 0.45–10.42)/2.8 (2.2)
Length of hospital stay, days†	5 (2–9; 0–24)/6.7 (5.9)
<i>N</i> = 91 patients, unless otherwise specified. ED, emergency department; SNF, skilled nursing facility; LTAC, long-term acute care facility; IQR, interquartile range. * <i>n</i> = 57 patients (patients undergoing endovascular procedures excluded). † <i>n</i> = 77 patients (hospital inpatients excluded).	

whereas most of the cases (65 of 91) required an urgent intervention within 1 day, such as angiograms, unstable vertebral fractures, spinal cord compression and progressive myelopathy, brain lesions with mass effect and neurologic deficits, and shunt revisions.

Our data show that among various subspecialties and patient populations, the adult functional and epilepsy subspecialty was the most impacted by practice modifications during the pandemic (18.1% vs. 5.5%) (Figure 1), which is not surprising, as most of the

functional/epilepsy interventions are classified as elective, which was an exclusion criterion for surgical staffing per the Battle Plan.¹⁰ The endovascular subspecialty had an 11.5% increase in the caseload, with various ranging from stroke interventions and diagnostic angiograms to embolization of aneurysms and arteriovenous malformations, among others. Although less common than other subspecialties, adult open vascular cases more than doubled compared with regular practice (2.4% vs. 6.6%) (Figure 1); these included carotid endarterectomies, resection of vascular malformations, and vascular bypass procedures. One would have expected that the numbers of adult spine cases would significantly decrease owing to their mostly elective nature; however, only a small decrease (2.9%) in the relative caseload was evident in this subspecialty, with an uptick in unstable traumatic fractures at different vertebral levels constituting 11 of 21 adult spine cases and 2 of 2 pediatric spine cases (Figure 1).

The median length of hospital stay of 5 days is especially low for this patient population with seemingly critical conditions; we believe that the enhanced efficiency in evaluating in-hospital patients for discharge planning is a consequence of the transfer of care strategy followed by the Battle Plan teams.¹⁰ Most of the patients (46 of 91) were discharged to their homes, while 7 died as a result of their complicated conditions. The mortality rate (7.7%) is quite high in this patient population, which is most probably due to the shift from a regular practice consisting of a mixture of elective and emergency surgical cases to a solely emergency practice during the pandemic. Teleclinic was again the preferred medium for follow-up, yet in-person clinic visits were necessary in some cases to ensure delivery of optimal postoperative care.

Study Limitations

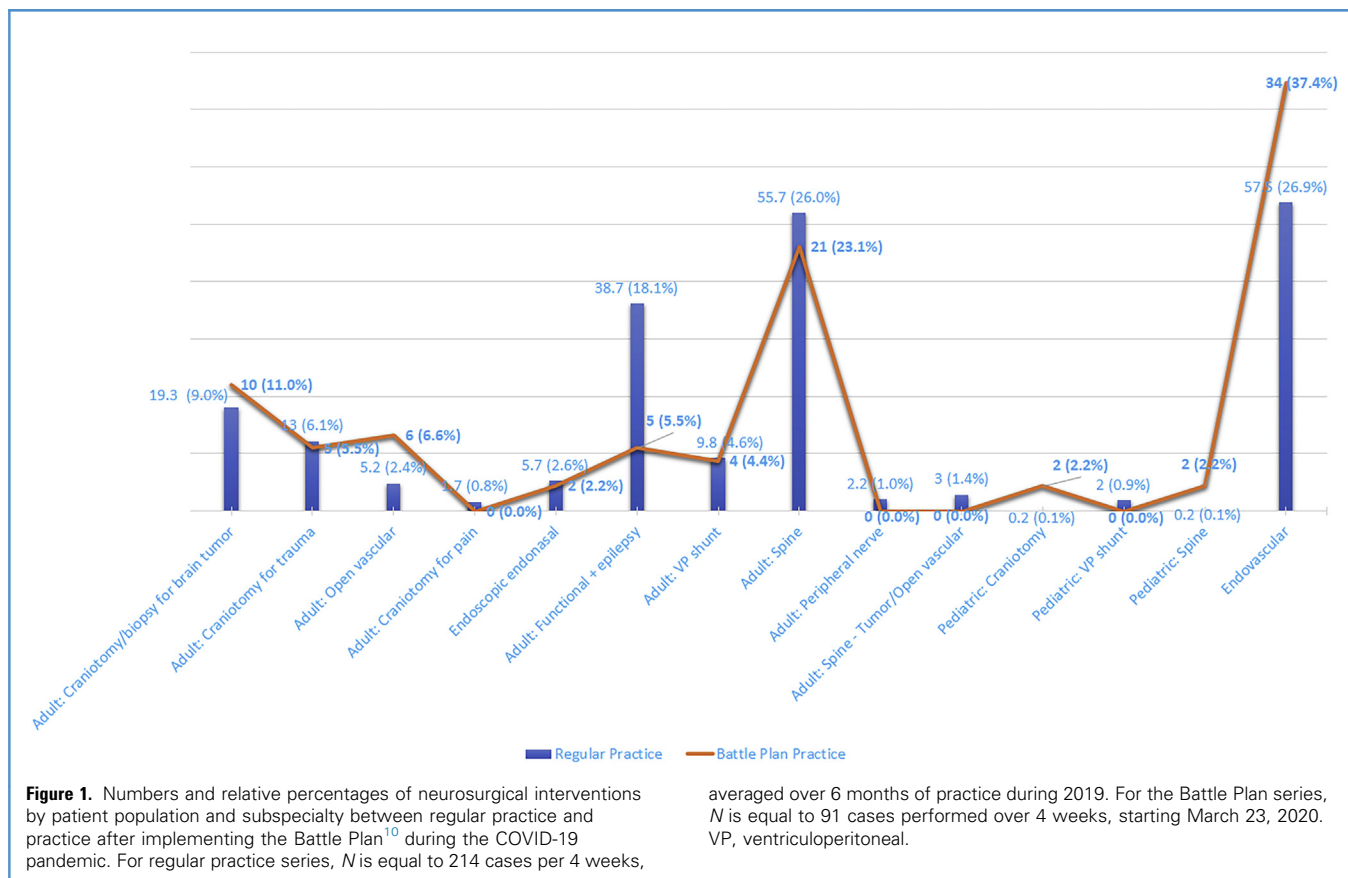
The patient population is relatively small, albeit unavoidable, owing to the short period (4 weeks) after implementing the Battle Plan, which may reduce the power of this study. Our experience with the Battle Plan is limited, and self-appraisal is an ongoing process during the pandemic.¹⁰

CONCLUSIONS

During a viral pandemic, implementation of crisis protocols will impact the caseload and variety of neurosurgical cases, but delivery of optimal care and safe practice and education at an academic neurosurgical department can be well maintained with proper execution of such protocols. Teleclinics proved to be efficient in screening patients for urgent neurosurgical conditions, but in-person clinic visits may still be necessary for some cases in the immediate postoperative period.

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Mohammad Hassan A. Noureldine: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Elliot Pressman:** Investigation, Resources, Data curation, Writing - review & editing. **Paul R.**



Krafft: Data curation, Writing - review & editing. **Mark S. Greenberg:** Supervision, Writing - review & editing. **Siviero Agazzi:** Supervision, Writing - review & editing. **Harry van**

Loveren: Supervision, Writing - review & editing. **Puya Alikhani:** Conceptualization, Methodology, Validation, Writing - review & editing, Supervision, Project administration.

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