Letter: The Coronavirus Disease 2019 Global Pandemic: A Neurosurgical Treatment Algorithm

To the Editor:

The recent outbreak of a novel coronavirus illness (coronavirus disease 2019; COVID-19) has grown into a global pandemic. As a response, there have been several treatment recommendations published by international, federal, state, and local governing bodies. Here, we aim to help neurosurgeons synthesize these recommendations into an institutional policy that fits the unique demands of neurosurgical practice. We performed a comprehensive review of COVD-19 policies and aggregated multidisciplinary expertise at our institution to formulate recommendations for scheduling surgery, providing neurosurgical coverage, and engaging in neurosurgical research during the COVID-19 outbreak. Here, we present a neurosurgical algorithm for varying levels of COVID-19 community infection. This algorithm (with an accompanying checklist) is centered around a 3-tiered system of viral "surge" quantification, which we use to triage case scheduling, and a paired coverage model (PCM), which we use to provide inpatient services. COVID-19 represents a challenge to ongoing practice; however, with clear algorithms, checklists, and contingency planning, it is possible to provide focused neurosurgical care during this pandemic.

INTRODUCTION

In late 2019, a new coronavirus disease emerged, and has been referred to as coronavirus disease 2019, abbreviated "COVID-19."[1-3] This virus initially caused a local infection of the city of Wuhan, China,[1,4,5] and then quickly spread to over 30 countries and was declared a global pandemic by the World Health Organization (WHO) on March 11, 2020.[6-12] As of March 13, 2020, there were 1629 cases and 41 total deaths in the United States, according to the statistics compiled by the Centers for Disease Control (CDC).[13] These cases have been concentrated in California, Washington, and New York; however, almost all states have reported cases of COVID-19. As our health-care system faces this outbreak, the most pressing issues facing neurosurgeons involve (1) the decision to cancel elective cases and outpatient clinics, (2) organizing staff (including advanced practitioners and resident physicians) to minimize exposure risk, and (3) handling neurosurgical emergencies in situations where intensive care unit (ICU) bed availability is compromised by an increasing number of COVID-19 patients.

Throughout this crisis, it is important to respect the nuances of COVID-19 policies set forth by local hospital systems and health-care institutions. However, such institutions often seek the advice of the neurosurgeon to synthesize national and international policy to formulate local treatment algorithms. This report is designed to aid neurosurgeons in this endeavor, and to serve as a reasonable starting point in making such local policy.

The situation regarding COVID-19 is rapidly evolving, and changes daily. Although timely policies should be implemented to facilitate objective decision-making, it is inevitable that such directives will need to adapt to this fluid environment. The challenge of COVID-19 for the neurosurgeon is to minimize the risk of transmission of the virus, while continuing to provide care for neurosurgical patients in need of urgent and emergent treatments. Here, we provide our institutional experience to serve as an example for neurosurgeons facing these issues related to the ongoing COVID-19 outbreak.

METHODS

Literature Review and Chinese Neurosurgical Experience

We first performed a literature review by submitting the terms "COVID-19" to PubMed. This yielded an initial set of 947 results, that were manually reviewed for relevance to neurosurgery, surgical case scheduling, and resident and advance practitioner staffing. Only articles in the English language were considered for this literature review. Once all relevant articles were identified, we extracted epidemiological information regarding the scheduling of surgical cases[14] and the need for ICU care.[15-17] We then used these data to form a multi-disciplinary panel from our institution in the departments of surgery, anesthesia and peri-operative care, critical care, hospital administration, and neurosurgery ("evidence review panel" (ERP)). In addition to this literature review, we sought the advice and expertise from neurosurgeons who had direct experience in China caring for neurosurgical patients during the COVID-19 outbreak. These neurosurgeons provided first-hand knowledge of how neurosurgical cases were scheduled during the peak of the COVID-19 outbreak in China. We included these recommendations as discussion points in our ERP. Because no patient data were used for this report, Institutional Review Board approval and patient consent was not sought or obtained. The Standards for Quality Improvement Reporting Excellence checklist was used when preparing the treatment algorithm.

Interdisciplinary Panel

Recommendations from the CDC, WHO, California State Department of Public Health, San Francisco Department of Public Health, and the University of California San Francisco (UCSF) School of Medicine were collected and reviewed by the ERP, and algorithms regarding the following issues were drafted: (1) neurosurgical case scheduling, (2) neurosurgical clinic scheduling, (3) contingency planning for neurosurgical staffing and ICU utilization, and (4) staffing neurosurgical research directives. These algorithms were formalized and distributed to the department, and communicated via email to all faculty, residents, and staff. Daily emails were used to document changes in the algorithms, enabling alterations based on rapidly evolving data and outbreak statistics.

Surge level	Emergent and urgent cases	Elective and procedural cases	Transfers
Green: 1-9 community cases, or <6 COVID+ inpatients, and No staffing shortages	- Ensure ORs and surgeons available to rapidly operate and discharge ED cases (appy/chole/hip fx) - Maintain capacity for urgent cases	- proceed - Review and schedule all cases 7 days in advance for quick cancellation should surge level increase to yellow	Per service protocol
Yellow: 10-99 community cases, or 7-16 COVID+ inpatients, or < 20% staffing shortages	- Ensure ORs and surgeons available to rapidly operate and discharge ED cases (appy/chole/hip fx) - Maintain capacity for urgent cases	- Cap OR schedule for next 3 weeks - 25% reduction in procedural cases requiring overnight stay (ERCP/cath/IR) - Ramp up come and go procedures at outpatient facility - Reschedule OR cases so no more than 25 post-op admits over next 7 days	Time sensitive protocol
Red: >100 community cases, or >17 COVID+ inpatients, or > 21% staffing shortages	- Ensure ORs and surgeons available to rapidly operate and discharge ED cases (appy/chole/hip fx) - Maintain capacity for urgent cases	- Cap OR schedule for next 3 weeks - 50% reduction in procedural cases requiring overnight stay (ERCP/cath/IR) - no use of PACU for recovery - Cancel come and go procedures - Reschedule OR cases so no more than 12 post-op admits over next 7 days	Closed to all transfers
Black: Significant assistance needed from outside institutions	Emergent cases only	- Cancel all scheduled cases	Closed to all transfers

FIGURE 1. *Volume limiting approach to elective scheduling. The surge level criteria are shown in the left column, the emergent case and the elective case recommendations are shown in the middle two columns, and the transfer center recommendations are shown in the right column. OR: operating room; ED: emergency department; appy: appendectomy; chole: cholecystectomy; hip fx: hip fracture; ERCP: endoscopic retrograde cholangiopancreatography; IR: interventional radiology; cath: cardiac catheterization; PACU: post-anesthesia recovery unit. Community cases refer to active cases in the local region.*

Final Algorithm and Checklist

Our goal was the enactment of an algorithm and contingency plan in order to allow for dynamic resource allocation to meet the needs of the outbreak, while also caring for neurosurgical patients. All essential clinical staff (faculty, residents, and advanced practitioners) were notified of their role based on rising levels of infection risk. Teams were formed based on models of emergent surgical "outbreak" coverage.[11] To facilitate communication across disciplines in crisis settings, we also devised a surgical checklist to be applied to neurosurgical cases. The checklist helped to focus attention on the barriers to booking urgent surgery during the pandemic. The final checklist and treatment algorithms were provided to faculty, residents, and advanced practitioners.

RESULTS

Scheduling Neurosurgical Cases

Based on our literature review, no publications specifically addressing a neurosurgical response to COVID-19 have been published since the outbreak in late 2019. Although articles have addressed the effect on outpatient clinics,[18] the virus' effect on the central nervous system,[19] and the preparation of the operating room (OR) for emergent surgeries for COVID-19 patients,[14] there have also been no studies on algorithms for scheduling neurosurgical cases during the pandemic. The American College of Surgeons (ACS) does recommend that surgeons postpone or cancel elective cases during the COVID-19 pandemic.[20] Although these recommendations are helpful, they do not address how to triage cases that require urgent neurosurgical scheduling (within ∼2 wk).

To adequately handle these cases, our ERP first created a system to quantify the "surge level" of the disease (Figure 1). Using this system, the current surge level is given a color code that correlates with the rising viral transmission threat to our community. The green, yellow, and red levels represent the lowest, moderate, and highest levels of surge, respectively. The black level corresponds to the need for significant resources outside of our institution. As Figure 1 indicates, in the green level, all elective cases proceed as scheduled. In the yellow level, the OR schedule is capped for 3 wk to 75% of capacity, yielding a 25% reduction in all elective and procedural cases. During this time, all outpatient procedures should be designated to an off-site hospital where COVID-19 patients are not expected to be admitted. In addition, there is a hard cap on the number of cases requiring post-operative admission. In the red level, these numbers are more strict.

Site 1: Main hospital			Site 2: VA hospital			Site 3: Trauma hospital			Site 4: Peds hospital			
Team 1	Team 2	Alternates	Team 1	Team 2	Alternates	Team 1	Team 2	Alternates	Team 1	Team 2	Alternates	Additional back-up coverage
PGY-2	PGY-2	PGY-2	PGY-4	PGY-7	PGY-7	PGY-4	PGY-7	fellow	PGY-3	PGY-4	fellow	fellow (spine)
PGY-3	PGY-3	PGY-5										fellow (spine)
PGY-6	PGY-6	PGY-5										fellow (peripheral nerve)
		PGY-5										fellow (tumor)
		PGY-6										fellow (vascular)

FIGURE 2. *Paired Coverage Model. The following model of team-based paired coverage will go into effect during red levels of COVID-19 (see Figure 1). In this model, each individual hospital (columns) will have 3 groups of providers: 2 teams that switch coverage on a 3-d cycle, and an alternate group that substitutes for any team member who shows signs of illness. In this way, if a team becomes contaminated, the other team will take over, and the alternates will fill the gap. Contact between teams and alternates is prohibited. VA: Veterans Affairs Peds: pediatric; PGY: post-graduate year (resident level).*

Namely, there is a 50% reduction in all elective case scheduling, and a 12 patient limit on postoperative admissions for all surgical cases (including non-neurosurgical cases). Finally in the black level, in which significant state or federal resources are needed to fight the outbreak, all urgent scheduled surgical cases will be canceled.

This system responds to a dynamic level of transmission surge, and is flexible in the kinds of cases allowed to proceed. In particular, by setting limits on the number of cases as opposed to the types of cases, it allows the surgeon to triage his or her own schedule. This "volume limiting approach" encourages maximal adaptability, in which the supply of hospital capability meets the demand of scheduling needs. In addition, the surgeon should reduce outpatient clinic volume by 25% in the yellow level and by 50% in the red level. In the black level, outpatient clinic should be canceled.

Finally, throughout all levels, neurosurgeons are encouraged to convert meetings (with staff, colleagues, and patients) to video conferencing. The neurosurgeon is provided with full information technology support to set up video conferencing and tele-health. At the surgeons' discretion, patient follow-ups and clinic appointments, when possible, should be converted to tele-medicine. In addition, consistent with policy from the San Francisco Department of Public Health and the California Department of Public Health, staff and patients over the age of 65 are encouraged to avoid coming to the hospital and clinic. In these situations, the surgeon should make every effort to engage in telemedicine and remote meetings.

Emergent Cases and Hospital Staffing

At all levels of outbreak, the algorithm in Figure 1 allows for emergent surgery. To care for these patients, neurosurgery services require 24 h in-house coverage, which is provided at our institution by resident physicians. It is thus important to develop a system to minimize patient and provider viral exposure, while also simultaneously ensuring uninterrupted inpatient coverage for neurosurgical emergencies.

The system that we have designed to meet these goals is shown in Figure 2. This system is based on the "paired coverage model." In this system, each hospital will be covered by 2, nonoverlapping teams. Each team will only rotate at 1 hospital (no cross-covering) and will only have contact with members within their team. Teams at the same site will not have any overlapping clinical time with each other. Teams will rotate in 3 d cycles: ie, each team will cover for 3 d, and then have 3 d off while the second team covers. The transition between teams will occur virtually, avoiding unnecessary team-to-team contact. This system ensures adequate coverage, minimizes hand-off issues, and, most importantly, minimizes transmission risk across teams.[11] Because the likelihood of infection is present among inpatient providers, there will be a designated "alternate pool" of providers that will substitute for those who show COVID-19 symptoms.

The PCM is triggered by a red level of surge (Figure 1). All residents are aware of their role in the PCM ahead of time. In addition, site-specific needs are addressed within the team. For example, teams at the main hospital in our institution are larger than teams at other satellite hospitals, given the large volume at the main hospital compared to the satellite hospitals. Thus, the PCM is adaptable such that the number of team members can vary, along with the experience level of the team. However, the core function of the PCM (limiting healthcare worker transmission of the virus) remains.

In addition to the PCM, it is also important that neurosurgeons provide their anesthesia colleagues, nursing staff, and the OR with objective data about which cases should be expected to proceed during a COVID-19 outbreak. Indeed, although it may be straight forward for neurosurgeons to predict what cases should be classified as an emergency, it will reduce ambiguity if the entire team is also aware of such cases. To that end, we developed a checklist that can be applied to neurosurgical case during the COVID-19 pandemic (Figure 3). Previous work has shown that checklists help organize surgical staff during times of crisis, such as guiding action during "red alerts" from neuromonitoring during spinal surgery.[21] Here, we adapt the checklist strategy to organize

Checklist for Neurosurgical Cases During COVID-19 Outbreak

Determine level of urgency of case:

- ☐ Assess for neurosurgical emergency (0-48 hours to OR). Emergent cases include:
  - ☐ cranial trauma/infection.... TBI, depressed skull fractures, space occupying lesions, empyema/abscess
  - ☐ cranial tumor .... pituitary apoplexy, tumor with mass effect
  - ☐ cranial vascular .... intracranial hemorrhage from ruptured aneurysm, AVM, and/or dAVF
  - ☐ cranial CSF diversion .... shunt obstruction, acute hydrocephalus
  - ☐ functional .... hardware infections, sudden DBS battery failures
  - ☐ spine .... spinal instability or spinal cord compression from fracture, tumor, or infection
  - ☐ spine, disc disease .... cauda equina, nerve root compression with progressive motor deficit
  - ☐ In addition, any case meeting the following criteria:
    - ☐ acute and progressive neurological symptoms referable to focal lesion on imaging, AND
    - ☐ determined to be an emergency by board certified neurosurgeon
- ☐ Assess for neurosurgical urgency (2-14 days to OR). Urgent cases include:
  - ☐ any case requiring surgery within a 14 day period that does not meet above criteria
- ☐ Assess for purely elective cases
  - ☐ any case not meeting criteria for urgent or emergent cases (defined above)

Determine availability of operating room:

- ☐ Blood is available in blood bank? If not, abort surgical scheduling
- ☐ Sufficient PPE (per infection control protocol) available? If not, abort surgical scheduling
- ☐ Assess viral surge level in the local community
  - If green, ☐ schedule elective and urgent cases, proceed with emergent cases
  - If yellow, ☐ schedule urgent cases, proceed with emergent cases
  - If red, ☐ schedule urgent cases per multi-disciplinary periop committee (surgeons + anesthesia), proceed with emergent cases
  - If black, ☐ proceed only with emergent cases only

Determine availability of post-operative beds:

- ☐ Assess need for ICU post-operatively
- ☐ Determine possibility of floor placement after surgery
- ☐ Check with nursing at designated post-operative destination for comfort receiving patient

Surgery was able to be scheduled with available post-operative bed secured?

- ☐ Yes, book surgery
- ☐ No
  - ☐ Repeat checklist for next 21 days to ensure no changes in status
  - ☐ If still unable to book surgery, explain to patient the need to cancel surgery, and re-schedule after COVID-19 outbreak

FIGURE 3. *Checklist for booking neurosurgical cases during COVID-19 outbreak.*

surgical staff around the common goal of booking cases during the outbreak (Figure 3). Distribution of the checklist to all surgical staff will facilitate effective communication and the ease with which appropriate neurosurgical cases can be scheduled.

Research Directives and Staffing

Finally, our institution has addressed how COVID-19 affects research directives. We have required that all staff not essential to clinical care stay at home. This applies to lab workers, research track faculty, postdoctoral fellows, and graduate students. Animal facilities will be run by institutional staff outside the Department of Neurosurgery. As of March 18th, the UCSF Office of Research will institute a shutdown of all noncritical research activities. Understanding that the needs of long-term viability of many research programs will require management of essential animal lines, equipment, liquid nitrogen stocks, and certain long-term experiments, they are permitting 1 to 2 designated key personnel who will be responsible for this essential maintenance. Larger laboratories are allowed to name up to 3 to 4 key personnel. It is advised to select key personnel whose commute does not depend on public transportation. In mouse facilities, breeding is to be reduced to a minimum. There will be no increases in cage counts permitted. For other facilities housing aquatic, avian, or United States Department of Agriculture-covered animals, basic animal care and husbandry operations are to continue. Studies related to COVID-19 itself are exempt from the requirements since they have the potential to mitigate the spread of the pandemic.

Staff with dual clinical and research roles (such as faculty, resident physicians, as well as clinic coordinators) are required to come in only if they are symptom free. During this time, if they have research time scheduled, research activities may be permitted. We have recommended that researchers working from home engage in writing projects, literature review, data analyses, or online learning (eg, computer coding and advanced statistics). Labs are charged with providing members with the ability to work remotely, including enabling virtual private network access. All new patient enrollments in on-going research studies are suspended.

DISCUSSION

COVID-19 is a global pandemic, and causes a severe infection that can lead to respiratory failure and death.[22] The death rate for COVID-19 is much higher than the typical influenza seasonal viral illness, and disproportionally affects the elderly and patients with major cardiopulmonary co-morbidities.[13] The high rate of transmission and virulence of COVID-19 is not only associated with a high mortality rate, but also risks putting such a strain on the health-care system that other patients will not be able to receive urgent treatments.[16] In particular, respiratory failure from COVID-19 leads to a high rate of intubation requiring ventilator beds, creating a shortage of ICU capacity, making the treatment of all critical diseases extremely difficult, or even impossible.[16] From a neurosurgical perspective, COVID-19 requires that the neurosurgeon balance the surgical needs of patients suffering from "urgent" diseases (eg, malignant brain tumors, spinal instability, and severe traumatic brain injury), with the need to allocate hospital resources for a possible outbreak. This report is designed to help the neurosurgeon with these difficult decisions.

After a thorough review of the literature, there are no current studies that address the strains on neurosurgical practice from COVID-19. Furthermore, although several studies address the general strategies to cope with the strain that COVID-19 may place on the hospital system,[6,15,17] specific recommendations for surgical practice are sparse. And, while the ACS lays out general principles,[20] a detailed COVID-19 surgical treatment algorithm has not been previously published. Thus, our tiered volume limiting approach to restricting OR access based on the current surge level of the virus is novel. This volume limiting approach allows for dynamic resource allocation. By contrast, an alternative model would be to rank every type of surgical case ahead of time, and then triage cases based on these rankings. However, the volume limiting approach is more fluid, and allows surgeons to triage on a case-by-case basis, permitting more flexible operative plans based on the surge level, OR availability, and need for emergent cases. Thus, although neurosurgeons may feel pressure to cancel cases due to fear of intra- and perioperative COVID-19 transmission, these algorithms and checklists identify objective criteria for doing so.

In addition, the PCM provides a flexible model of how to cover critically ill patients during COVID-19. Again, the basis of the model is identifying levels of COVID-19 surge using objective criteria of the presence of the viral outbreak level in the local community. Once triggered, the PCM allows for neurosurgical coverage while also minimizing the possibility of interteam transmission. Having a plan to provide coverage and handle emergency procedures ensures the functioning of the neurosurgery service despite increasing levels of community and hospital COVID-19 infections.

Although our algorithms and checklists provide objective criteria to help neurosurgeons develop local protocols for

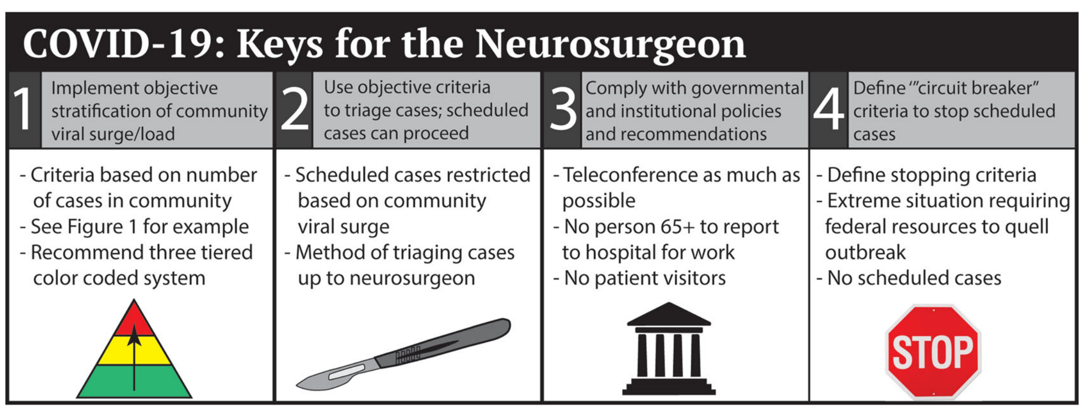

FIGURE 4. *COVID-19 for the neurosurgeon: summary and take-away points.*

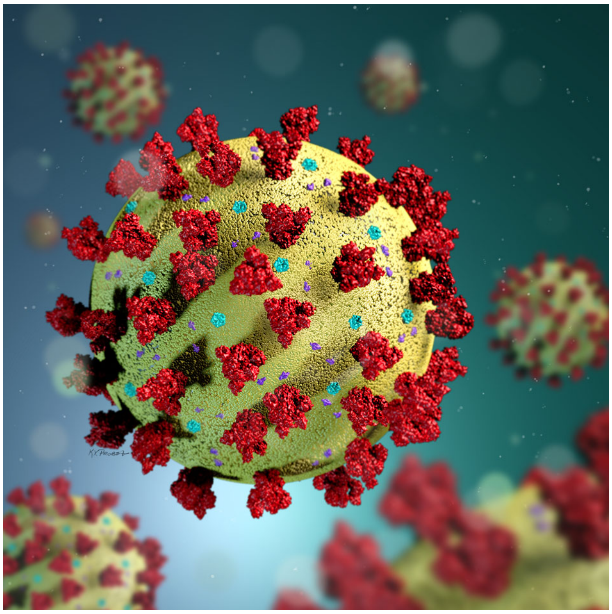

FIGURE 5. *Illustration of SARS-CoV-2, the pathogen of the COVID-19 global pandemic.*

COVID-19 outbreaks, there are a number of limitations in this study. First, most of the criteria are specific to one institution. Although the principles apply to other systems, the algorithms and checklists will need to be adapted accordingly. Second, our PCM requires a pool of resident physicians of different levels in order to implement. This may be translatable to other academic centers; however, neurosurgeons in smaller centers may have difficulty implementing PCM coverage. Finally, our surge level system requires knowledge about the number of cases in the community, which may not be obtainable in all practices.

CONCLUSION

We have established a set of algorithms and checklists for scheduling of neurosurgery cases (Figure 4), as well as neurosurgical coverage during the COVID-19 pandemic (Figure 5). These algorithms may be used as an example when implementing protocols in local neurosurgical practices; however, such protocols should adhere to local institutional polices and directives.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article. Dr Chan has research support for nonrelated study from Orthofix, Inc. Dr Chou is a consultant for Globus and Medtronic. Dr Praveen Mummaneni is a consultant for DePuy Spine, Globus, and Stryker, has direct stock ownership in Spinicity/ISD, receives clinical/research support from NREF, receives royalties from DePuy Spine, Thieme Publishers, and Springer Publishers, and has grants from AOSpine and ISSG.

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Acknowledgments

We thank the visiting neurosurgical faculty from China who helped and advised us in the formulation of these algorithms and checklists: Bo Li, Jing Ping Liu, and Rong Xie.

10.1093/neuros/nyaa116