Novel coronavirus disease 2019 (COVID-19) was first reported in the city of Wuhan, China, in December 2019. Since that time, there has been an exponential increase in the number of cases, from a few hundred to 8.3 million at the time of this writing. This increase has been accompanied by a meteoric rise in the literature on COVID-19, with more than 18,000 publications reported to date. As the number of scientific reports increases daily, it becomes imperative to filter the grain from the chaff and provide updates and recommendations for the neurosurgical discipline, where practice patterns have seen a sea change. The already-overburdened healthcare delivery systems of developing countries like India have come under severe stress due to the rapid increase of cases. At the time of the submission of this paper for publication, more than 367,000 positive cases with more than 12,000 deaths have been attributed to COVID-19 in India. We have adapted and restructured our treatment and resource allocation to improve healthcare delivery. In this article, we share our experience and present a comprehensive review of guidelines, suggestions, and recommendations pertaining to neurosurgical practice in a developing country amid the COVID-19 pandemic. Our replicable patient triage algorithm, management protocols, and template for judicious manpower reallocation can be useful for many centers dealing with the pandemic. To prepare this article, we carried out a review of articles on PubMed on June 4, 2020, by using the keywords “COVID-19” and “neurosurgery.” The search yielded 295 articles, which we reviewed for relevance. References from relevant articles were reviewed to locate other articles of interest. Additionally, documents published on websites of various international and national neurosurgical and relevant medical societies were also included.1–7
manpower for medical management of COVID. We discuss each of these topics in detail in light of the published literature and our experience.

Reorganization of Infrastructure and Manpower

A pertinent example of restructuring of manpower and infrastructure comes from Lombardy, Italy, an area heavily affected by the COVID-19 pandemic. Neurosurgeons in Lombardy employed a “hub-and-spoke” scheme wherein all urgent neurosurgical activity of the region was clustered among three centers (Niguarda, Brescia, and Varese, called emergency neurosurgical hubs). Apart from these three centers, only one other center (the Carlo Besta Neurological Institute in Milan, Italy) functioned as the regional centralizing neurosurgery hub for nondeferrable tumor cases. With the cooperation of neurosurgeons from “spoke” hospitals, the number of on-duty neurosurgeons in the “hub” hospitals doubled, and all neurosurgical units in the spoke hospitals became inactive within a week. This and the reduction of all elective surgery in the region was an effort to preserve ICU beds for COVID-19 patients. A similar model was employed in our city (New Delhi, India), where certain hospitals were designated as COVID-19 facilities so as to concentrate healthcare manpower and resources—ventilators, personal protective equipment (PPE), intensive care facilities, etc.—for optimal management of COVID-19 patients, without compromising the safety of non–COVID-19 patients. Along similar lines, our institute, having a bed capacity of > 3000, designated two separate satellite centers, the National Cancer Institute and the Trauma Centre, as COVID-19 facilities. The centers have a capacity of > 800 patients (National Cancer Institute) and > 200 patients (Trauma Centre), with the former primarily for patients with mild symptoms and the latter for patients with moderate or severe symptoms requiring assistive ventilation and intensive monitoring. This setup ensured physical and spatial distancing of COVID-19 facilities from non–COVID-19 facilities, reducing COVID-19 cross-infection and optimizing cost-effective utilization of PPE and hospital resources. A centralized database of the number of COVID-19 beds and ventilators available in our city enabled real-time tracking by using an app to streamline the processes of patient referral, testing, triage, and admission.

With the reduction or cessation of elective procedures, the need for doctors required for inpatient care decreased. Thus, in order to optimize resource utilization, Burke et al. recommended a “paired-coverage model” of resident physicians and healthcare providers (HCPs). In this model, each individual hospital has three HCP groups: two teams that switch coverage on a 3-day 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. Many other authors have recommended a similar model. We used a similar strategy in our department, in which we divided 40 residents and 25 faculty members into three teams, with distribution among the teams of neurosurgeons of various specialties so that each group had similar experience levels and expertise in each of the areas of vascular, trauma, neuro-oncology, spine, functional, and pediatric neurosurgery. Each team was on call for a week and then responsible for self-quarantining for the next 2 weeks. In cases in which more than 50% of any team was subjected to high-risk exposure to COVID-19—positive patients or staff, or became symptomatic, the next team would take over and so on. This enabled us to render neurosurgical care in our setting with maximum efficiency with approximately 100 neurosurgical beds at disposal.

Clinic Scheduling and the Role of Telemedicine

During this COVID-19 pandemic, increasing numbers of hospitals and doctors have relied on teleconsultations for patient follow-ups, leading to decongestion of hospitals, timely treatment, and decreased exposure to COVID-19. Since March 2020, the telemedicine encounters at Johns Hopkins Hospital (Baltimore, MD) have increased 1000-fold. Similarly, the number of clinic visits at Jackson Memorial Hospital (Miami, FL) has decreased by 80% since the shift to telemedicine. Most hospitals providing teleconsultation services have received positive feedback from both patients and providers. Similarly to the results reported for these two US hospitals, we had to resort to teleconsultations as a primary mode of outpatient consultations during the nationwide lockdown in India. We observed that it is easier to assess and advise patients regarding routine postoperative checks, vascular pathology, and brain tumors. Other pathologies requiring subtle examination findings, such as peripheral nerve and spine pathologies, are more difficult to assess via telemedicine.

Other important issues that must be redressed to improve the practice of telemedicine include medicolegal and reimbursement procedures, interstate licensure, malpractice liability, and technological challenges. We have realized that these teleconsultation platforms were hugely underutilized and can also be used in the future for select groups of patients. Our neurosurgery center is a high-volume referral center, with a daily visit rate of almost 600 patients at our clinics. In accordance with the recommendations of our institute’s hospital infection control committee (HICC), we formulated guidelines to streamline patient flow to ensure patient safety and minimize the exposure of HCPs without compromising patient care. In formulating these guidelines, we dealt with key issues that included strictly maintaining social distancing, minimizing patient stays in hospital premises, and providing adequate protection of staff by using appropriate designated PPE levels (Table 1) and frequent disinfection of surfaces and environments, having a separate area for consulting patients with respiratory symptoms, and performing thermal screening of all visitors at entrances.

Surgical Scheduling

Triaging of Neurosurgical Procedures

Globally, neurosurgeons reduced their frequency of performing elective neurosurgical procedures at the peak
of the pandemic to preserve supplies, PPE, blood products, and ICU beds and to minimize the exposure of HCPs to COVID-19. We reviewed the recommendations of multiple neurosurgical societies, and our experience also corroborates their plans to triage neurosurgical procedures to provide the best possible treatment. The American College of Surgeons recommended that surgeons and hospitals consider postponing all elective surgeries until a decrease in new COVID-19 cases is achieved and the expanded healthcare infrastructure is able to support all cases. The European Association of Neurosurgical Societies recommends triage of neurosurgical cases using a tiered approach based on emergency status classification. Another noteworthy protocol is the Mount Sinai Neurosurgery Management algorithm, which has been designed while keeping in mind the challenges faced by hospitals.

### TABLE 1. HICC guidelines for the use of PPE in different hospital settings

| Target Personnel/Pts                  | Activity                  | PPE                                      |
|---------------------------------------|---------------------------|------------------------------------------|
| **Designated COVID-19 areas**         |                           |                                          |
| ICU                                   | AGP                       | Level III kit w/ face shield             |
| Healthcare workers (doctor/nurses/technicians) | Disinfection/pt shifting | Level III kit w/ heavy-duty gloves & boots |
| SA/HA                                 |                           |                                          |
| Ward                                  | Non-AGP                   | Level II kit w/ face shield for AGPs     |
| Healthcare workers (doctor/nurses/technicians) | Disinfection/pt shifting | Level II kit w/ heavy-duty gloves & boots |
| Emergency screening area              | Screening/sampling        | Level II kit w/ face shield for AGPs     |
| Healthcare workers (doctor/nurses)    |                           |                                          |
| SA/HA                                 | Disinfection/pt shifting  | Level II kit w/ heavy-duty gloves & boots |
| **Transport of COVID-19–suspected/–confirmed case in ambulance** |                           |                                          |
| Ambulance (healthcare workers traveling in pt compartment) | Attending pt (direct contact >15 mins) | Level II kits |
| Healthcare workers (doctor/nurses)    |                           |                                          |
| SA/HA                                 | Disinfection/pt shifting  | Level II kit w/ heavy-duty gloves & boots |
| Driver                                | No direct contact         | N95 masks                                |
| **Designated non–COVID-19 areas**     |                           |                                          |
| Emergency medicine                    |                           |                                          |
| Healthcare workers (doctor/nurses/technicians) | Non-AGP | Level I kit; face shield for AGPs |
| SA/HA                                 | Disinfection/pt shifting  | Level I kit w/ heavy-duty gloves         |
| General out-pt/EHS out-pt             |                           |                                          |
| Healthcare workers (doctor/nurses)    | Non-AGP                   | Level I kit                              |
| SA/HA                                 | Disinfection              | Level I kit w/ heavy-duty gloves         |
| General ward/private rooms            |                           |                                          |
| Healthcare workers (doctor/nurses)    | Non-AGP                   | Level I kit; face shield (for AGPs)      |
| SA/HA                                 | Disinfection/pt shifting  | Level I kit w/ heavy-duty gloves         |
| ICU                                   | AGP in non–COVID-19 area  | Level II kit w/ face shield              |
| Healthcare workers (doctor/nurses/technicians) | Disinfection/pt shifting | Level II kit w/ heavy-duty gloves & boots |
| EHS dispensary                        |                           |                                          |
| Pharmacist                            | Drug dispensing           | N95 mask                                 |
| Laboratory personnel                  |                           |                                          |
| Doctors/technicians                   | Dealing w/ respiratory samples | Level II kit |
| Radiodiagnosis                        |                           |                                          |
| Doctors/technicians                   | Non-AGP                   | N95 mask                                 |
| Administrative offices                |                           |                                          |
| All staff                             | No direct pt contact      | N95 mask                                 |
| **Confirmed/suspected COVID-19 case** |                           |                                          |
| Pt                                    | Droplet prevention        | Triple-layered mask                      |

AGP = aerosol-generating procedure; EHS = employee health scheme; HA = hospital attendant; pt = patient; out-pt = outpatient; SA = sanitation attendant. Level I = gown-based PPE kit; gown + N95 mask + goggles + gloves. Level II = coverall (same material as gown)–based PPE kit; coverall + N95 + goggles + long shoe cover + gloves. Level III = coverall (Tyvec/Tychem/Kimberly Clark)–based PPE kit; coverall + N95 + goggles + long shoe cover + gloves.
Within the epicenter of the pandemic, because New Delhi, India, was a hotspot for the COVID-19 pandemic at the time of this writing, we were withholding elective neurosurgical procedures and following a structured model to ascertain the urgency of neurosurgical intervention based on risk to life, impending neurological impairment, pathology, and COVID-19 status. Specific conditions are likely to require the interventions listed as follows. Emergency surgery—head injury with large extradural/subdural hematoma/confusion, malignant middle cerebral artery infarct, large supratentorial/basal ganglia/posterior fossa bleed, aneurysmal subarachnoid hemorrhage, hydrocephalus, malignant brain tumor with impending herniation/bled/significant mass effect, pituitary apoplexy, ruptured open neural tube defect, and intracranial abscess/subdural empyema. Semi-emergency surgery—cauda equina syndrome, large intracranial benign tumors (meningioma, schwannoma, giant pituitary adenoma, craniopharyngioma), large low-grade glioma with mass effect, unruptured intracranial aneurysm, posterior fossa tumors (medulloblastoma, ependymoma, etc.), spinal tumors with progressive myelopathy, and unstable spinal injury with neurological deficits. Elective surgery—benign small intracranial tumors (meningioma, schwannoma, pituitary adenoma, cavernoma, craniopharyngioma), congenital spinal or intracranial abnormalities, tethered cord syndrome, unruptured intracranial arteriovenous malformation and moyamoya disease, small low-grade glioma (asymptomatic or mildly symptomatic), degenerative spinal pathology, functional and epilepsy procedures, brachial plexus and peripheral nerve injuries and tumors, cranioplasty, and spinal tumors without myelopathy.

Preoperative Evaluation, Diagnostic Testing, and Decision Making

Chinese neurosurgeons recommend a detailed clinical screening along with pulmonary CT and real-time reverse transcription–polymerase chain reaction (RT-PCR) studies for all patients prior to hospitalization for nonemergency cases. The Indian Council of Medical Research...
The ICMR has issued guidelines for a testing strategy for COVID-19 in India. The latest version mandates testing of all symptomatic patients, their direct and high-risk contacts, and all hospitalized patients who develop ILI/SARI symptoms. Most of the eminent centers around the world and many prominent surgical societies recommend mandatory preoperative testing of patients (Table 5). The ICMR has not yet mandated testing for all hospitalized patients because of resource constraints. However, if the facilities are available, we recommend testing of all hospitalized patients and patients for whom elective/semi-emergency procedures are planned. There is a growing body of evidence in favor of this policy because surgery in patients with COVID-19 who are asymptomatic or presymptomatic leads to cross-infection and possible hazardous outcomes. In our center, until recently, real-time RT-PCR (the gold standard test) was the only diagnostic modality available. More recently, kits for cartridge-based nucleic acid amplification tests (CB-NAATs) and chip-based PCR assays (TrueNAT) have been made available and are being judiciously used to rapidly screen most of the emergency cases for which we cannot await the results of real-time RT-PCR. Some authors recommend revision of hospital protocols to delimit a precise route for the transfer of patients with suspected and confirmed cases in order to avoid cross-infection of other patients and unprotected personnel. This may be done by “cohorting,” separ-
rating suspected COVID-19 patients by using dedicated wards, ICUs, elevators, and corridors and avoiding buffer zones such as recovery rooms.  

Similarly, we created a designated ICU to care for patients in whom COVID-19 was suspected but not confirmed, until their testing reports came back. To streamline the movement of patients through the COVID-19–suspect ICU, separate entry and exit areas were earmarked along with their respective PPE donning and doffing areas. Personnel were required to use a dedicated stretcher with disposable protection that could be disinfected well after use.  

In addition, the residents and staff on duty in the COVID-19–suspect ICU worked in 6-hour shifts wearing optimal level II PPE including a face shield (Table 1). Once the test results were known, patients were shifted accordingly to the COVID-19–designated ICU facility or the COVID-19–negative ICU. This method of providing an ICU for patients suspected to have COVID-19 helps to streamline patient care and avoid unnecessary delays in treatment allocation as well as allaying apprehensions among HCPs about providing optimal patient care, because the same precautions are taken as for the COVID-19–positive ICU. For emergency surgeries, we try to get CB-NAAT/TrueNAT assays done and triage the patients accordingly (Fig. 2). In emergency cases for which the results are still pending or are unavailable, patients are taken directly to the COVID-19–suspect OR with negative-pressure ventilation with HEPA filtration. Adequate precautions akin to those used in the COVID-19 OR are taken in the form of appropriate PPE donning/doffing, use of appropriate PPE level, disinfectant use for surfaces, etc., by all OR staff to ensure minimal risk of cross-infection to HCPs. For semi-emergency cases, real-time RT-PCR is the preferred diag-

| TABLE 3. Checklist for coverall-based donning/इकाई के लिए जांच सूची |
|------------------|----------------------------------------------------------------------------------|
| Step No. क्र. सं. | Procedure/कार्य, यथानिर्देश | Yes/No हाँ/ना |
| 1               | Wash hands w/ soap & water/मासून और पानी से हाथ घोंले | हाँ/ना |
| 2               | Don 1st pair of gloves/दस्ताने की पहली जोड़ी पहनें | हाँ/ना |
| 3               | Don coverall/कवरॉल पहनें | हाँ/ना |
| 4               | Don shoe cover/जूतों के कवर पहनें | हाँ/ना |
| 5               | Don mask/ respirator (check for any leaks)/मास्क की कवरॉल से जोड़ी बांधने | हाँ/ना |
| 6               | Don goggles/ face shield/मास्क, सफेद सतह पर पहनें | हाँ/ना |
| 7               | Don hood/ हूड पहनें | हाँ/ना |
| 8               | Don 2nd pair of gloves/दस्ताने की दूसरी जोड़ी पहनें | हाँ/ना |
| 9               | Gown fitness check (ask buddy to help)/माओन फाटने की जांच कर (मदद के लिए साथी से करें) | हाँ/ना |

| TABLE 4. Checklist for PPE doffing/इकाई के लिए जांच सूची |
|------------------|----------------------------------------------------------------------------------|
| Step No. क्र. सं. | Procedure/कार्य, यथानिर्देश | Yes/No हाँ/ना |
| 1               | Check for any leak or soil in PPE before doffing (disinfect site if contaminated)/हाथों में निकालें पीपीई में कवरॉल व रिपी दोनों के साथ HCP की मासून के तरीके करें (साइट की ज़ेम बांधने के, अगर दृश्य है) | हाँ/ना |
| 2               | Disinfect the hands while wearing gloves (similar to hand hygiene procedure)/हाथों के लिए साफ घोंले जोड़ी हाथ के तरीके करें (साइट के, अगर दृश्य है) | हाँ/ना |
| 3               | Remove shoe covers only by touching the outer surface (by sitting on DIRTY chair)/जूते के बाहर के, अगर दृश्य है | हाँ/ना |
| 4               | Perform hand hygiene/हाथों को साफ करें | हाँ/ना |
| 5               | Remove outer gloves/हाथों से बाहरी दस्ताने को निकालें | हाँ/ना |
| 6               | Perform hand hygiene/हाथों को साफ करें | हाँ/ना |
| 7               | Remove hood/ हूड निकालें | हाँ/ना |
| 8               | Remove hand hygiene/हाथों को साफ करें | हाँ/ना |
| 9               | Remove new pair of gloves/ हाथों को नई दस्ताने को पहनें | हाँ/ना |
| 10              | Remove coverall/कवरॉल हटाएं | हाँ/ना |
| 11              | Remove goggles/face shield/मास्क, सफेद सतह पर निकालें | हाँ/ना |
| 12              | Perform hand hygiene/हाथों को साफ करें | हाँ/ना |
| 13              | Remove 2nd pair of gloves/दस्ताने की दूसरी जोड़ी निकालें | हाँ/ना |
| 14              | Perform hand hygiene/हाथों को साफ करें | हाँ/ना |
| 15              | Don new pair of gloves/दस्ताने की नई जोड़ी पहनें | हाँ/ना |
| 16              | Remove mask (do not touch front of mask, handle w/ slings/बां船ों के हैट) (मास्क की नींव में सघन, ठहराने के साथ) | हाँ/ना |
| 17              | Perform hand hygiene/हाथों को साफ करें | हाँ/ना |
| 18              | Clean shoes w/ alcohol swabs (sitting on CLEAN chair)/जूते को साफ करें (सवास या बांह) | हाँ/ना |
| 19              | Remove last pair of gloves & perform hand hygiene/दस्ताने की अंतिम जोड़ी निकालें और हाथों को साफ करें | हाँ/ना |

All PPE to be discarded in red bag. This red bag to be placed inside another red bag and sent for treatment (double bagging). Note: सभी पीपीई की लाल बांग में होट दाड़ी जांच करें। इस लाल बांग को दूसरे लाल बांग के अंदर रखें। आगामी और प्री-रोलर्स के लिए में जाएगा (“डबल बांग” में)।
| Authors & Year       | Country/Region or US State | Institute                                      | Confirmed Cases (country, region, or US state) | Preop COVID-19 Testing Recommendation                                                                 |
|----------------------|-----------------------------|------------------------------------------------|------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Boffa et al., 2020   | US/CT                       | Yale                                           | 44,994 (CT)                                    | Pts should be tested w/in 24 hrs preop & screened preop morning for Sx & temperature                   |
| Kessler et al., 2020 | US/NY                       | Mount Sinai Hospital                           | 387,402 (NY)                                   | Pts generally considered COVID-19 positive until proven otherwise; as available, multiple rounds of testing sent ASAP |
| Daci et al., 2020    | US/MA                       | UMass Memorial Health Care, Worcester          | 105,395 (MA)                                   | Preop testing of all op pts                                                                            |
| Eichberg et al., 2020| US/FL                       | Jackson Memorial, Miami                        | 73,544 (FL)                                    | Preop screening of all op cases; impose 14-day delay if testing not available                           |
| Zacharia et al., 2020| US/multicenter recommendation based on expert opinion |                                                   |                                                  | Emergency: assume COVID-19 positive; urgent: preop test if available as close as possible to op; quarantine until result negative; if test unavailable, assume COVID-19 positive; semi-urgent: test if available, if unavailable self-quarantine 14 days |
| Turri-Zanoni et al., 2020 | Italy/Lombardy           | University of Insubria, Varese                | 91,204 (Lombardy)                              | Mandatory definition of pt COVID-19 status even if asymptomatic: nasopharyngeal swabs complemented w/ chest imaging, immunological antibody determination, & saliva viral load quantification |
| Cenzato et al., 2020 & Perin et al., 2020 | Italy/Lombardy           | Carlo Besta Neurological Institute, Milan      | 91,204 (Lombardy)                              | All admitted pts: thorough screening w/ body temperature, O₂ saturation, CRP, transaminases, CBC, chest radiography, pharyngeal SARS-CoV-2 swab, & thorough clinical history; emphasis on ensuring hospital “COVID-19 free” per “hub-&-spoke” policy |
| Molliqaj & Schaller, 2020 | Switzerland/Geneva        | Geneva University Medical Center              | 31,094 (Switzerland); 5142 (Geneva)            | Emergency cases: deemed positive; urgent cases: op after testing                                       |
| Tan et al., 2020     | China/Hubei                 | Tongji Hospital, Wuhan                        | 68,135 (Hubei)                                 | Clinical screening in out-pt department; pulmonary CT & nucleic acid sequencing of throat swab recommended for preliminary COVID-19 diagnosis prehospitalization; direct emergency op performed for life-threatening pt condition |
| Chibbaro et al., 2020 | France/Alsace             | Strasbourg University Hospital, Alsace         | 157,000 (France)                               | Emergency: no need for swab; deferrable: management postswab; op deferrable ≥48 hrs, & expedited w/in 7–15 days; elective: management postswab; op rescheduled w/ in 2–4 mos |
| Kolias et al., 2020  | UK/Cambridge                | Addenbrooke’s Hospital, Cambridge             | 294,000 (UK)                                   | Pt Sx screened 1 wk prior & asked to self-isolate; 2 nasopharyngeal swabs preop (day 4–5 & day 2); pts w/ 2 negative swabs admitted on day of op & screened again for any COVID-19 Sx |
| COVIDSurg Collaborative, 2020 | South Korea/Seoul         | Yonsei University College of Medicine          | 12,085 (South Korea)                           | All pts screened for respiratory Sx & tested for COVID-19 preop                                      |
| Oudrhiri et al., 2020 | Morocco/Rabat              | WFNS Rabat Reference Centre ONO Hospital       | 8734 (Morocco)                                 | Initial assessment w/ pulmonary CT; COVID-19 testing of suspected cases                                |
| Lo et al., 2020      | Singapore                   | Singapore General Hospital                     | 40,604 (Singapore)                             | All pts: clinical screening & exposure history questionnaire, preop chest radiography; preop swab for all elective high-risk op pts (transgressing upper airways) |

CONTINUED ON PAGE 8 »
for a patient who is COVID-19 positive until their test is negative. If the procedure is deemed strictly necessary for patient survival, then the lifesaving surgery may be done, with the surgical team and the entire OR staff wearing enhanced level III PPE, not only for the entire duration of surgery but also for the whole of the patient’s stay in the OR. For COVID-19–negative patients, optimal individual protection standards should be maintained in consideration of the significantly high rates of false-negative results of the diagnostic tests currently used.5,23,36,44

**Patient Data**

For the purpose of illustration of data, we have divided the COVID-19 period in our setup into 5 phases based on the timelines of the first 5 nationwide lockdown periods (approximately 14 weeks each) (https://en.wikipedia.org/w/index.php?title=COVID-19_pandemic_in_India&oldid=966630532), and compared our data with the COVID-19 burden in the community (Table 6) (https://en.wikipedia.org/w/index.php?title=COVID-19_pandemic_in_Delhi&oldid=966360865; https://en.wikipedia.org/w/index.php?title=COVID-19_pandemic_in_India&oldid=966630532). Among the 351 inpatients we treated during this time period, 42 patients turned out to be COVID-19 positive (approximately 12%) during the emergency triage. Overall, 170 patients underwent surgery (21.2% suspect/indeterminate COVID-19 cases and 78.8% COVID-19–negative cases), including 3 asymptomatic patients who turned out to be COVID-19 positive after surgery (cumulative incidence of delayed COVID-19 positivity 3/170 = 1.76 per 100 operated asymptomatic neurosurgery patients).

**Intraoperative Management**

As a protocol, our department has made it mandatory to obtain a separate COVID-19 consent for each operative patient, as there is risk of acquiring nosocomial COVID-19 infection in otherwise noninfected patients, despite taking adequate precautions. Similar to prior recommendations, we use dedicated negative-pressure ORs with a preestab-
Patients transferred to the main neurosurgical facility when the trauma center was repurposed for care of COVID-19 patients.† Patients already admitted in the main COVID-19–negative facility on March 25, 2020.‡ One patient with severe traumatic brain injury (E1VtM2 at admission) who was COVID-19 indeterminate prior to surgery turned out to be positive after surgery. This patient died due to raised intracranial pressure. The incidence of COVID-19 positivity was determined to be 2.78 per 100 asymptomatic surgery patients suspected to have COVID-19.§ Two patients, one with a right basal ganglia hypertensive bleed and one with an anterior communicating artery aneurysm with a subarachnoid hemorrhage, who were negative for the SARS-CoV-2 virus prior to surgery (false-negative testing possibly due to inherent RT-PCR test limitations/viral incubation period/improper tissue sampling) turned out to be COVID-19 positive after surgery during re-testing (one patient during active surveillance for high-risk contact with a COVID-19–positive person in the ICU and the other patient due to development of symptoms pertaining to SARI). Both patients had good outcomes at discharge. The incidence of delayed COVID-19 positivity was 1.49 per 100 operated asymptomatic COVID-19–negative patients.

### TABLE 6. COVID-19 pandemic nationwide lockdown phases and neurosurgical case distribution at our center during 2020

| Phase | March 25–April 14 | April 15–May 3 | May 4–17 | May 18–31 | June 1–30 | Total |
|-------|------------------|---------------|---------|-----------|-----------|-------|
| No. of confirmed COVID-19 cases in India | 10,296 | 29,448 | 50,664 | 91,216 | 384,697 | 566,321 |
| Average cases per day in India | 490 | 1550 | 3619 | 6515 | 12,823 |
| No. of confirmed COVID-19 cases in Delhi | 1530 | 2988 | 5206 | 10,089 | 67,516 | 87,329 |
| Average cases per day in Delhi | 73 | 157 | 372 | 721 | 2251 |

| Phase | March 25–April 14 | April 15–May 3 | May 4–17 | May 18–31 | June 1–30 | Total |
|-------|------------------|---------------|---------|-----------|-----------|-------|
| New admissions | 36 + 44* + 56† | 35 | 49 | 39 | 92 | 351 |
| Total COVID-19–positive pts | 5 | 4 | 7 | 7 | 19 | 42 |
| Pts discharged | 61 | 31 | 27 | 23 | 79 | 221 |
| Total op pts | 25 | 26 | 35 | 24 | 60 | 170 |
| COVID-19–positive cases preop | 0 | 0 | 0 | 0 | 0 |
| COVID-19–indeterminate/suspect cases preop | 12 | 8 | 6 | 4‡ | 6 |
| COVID-19–negative cases preop | 13 | 18 | 29 | 20§ | 54§ | 134 |
| Overall mortality (%) | 10 (7.35) | 3 (8.57) | 6 (12.24) | 6 (15.38) | 14 (15.21) | 39/351 (11.11) |
| Op mortality (%) | 2 (8.0) | 1 (3.8) | 3 (8.57) | 2 (8.33) | 5 (8.33) | 13/170 (7.64) |

* Patients transferred to the main neurosurgical facility when the trauma center was repurposed for care of COVID-19 patients.
† One patient with severe traumatic brain injury (E1VtM2 at admission) who was COVID-19 indeterminate prior to surgery turned out to be positive after surgery. This patient died due to raised intracranial pressure. The incidence of COVID-19 positivity was determined to be 2.78 per 100 asymptomatic surgery patients suspected to have COVID-19.‡ One patient with severe traumatic brain injury (E1VtM2 at admission) who was COVID-19 indeterminate prior to surgery turned out to be positive after surgery. This patient died due to raised intracranial pressure. The incidence of COVID-19 positivity was determined to be 2.78 per 100 asymptomatic surgery patients suspected to have COVID-19.§ Two patients, one with a right basal ganglia hypertensive bleed and one with an anterior communicating artery aneurysm with a subarachnoid hemorrhage, who were negative for the SARS-CoV-2 virus prior to surgery (false-negative testing possibly due to inherent RT-PCR test limitations/viral incubation period/improper tissue sampling) turned out to be COVID-19 positive after surgery during re-testing (one patient during active surveillance for high-risk contact with a COVID-19–positive person in the ICU and the other patient due to development of symptoms pertaining to SARI). Both patients had good outcomes at discharge. The incidence of delayed COVID-19 positivity was 1.49 per 100 operated asymptomatic COVID-19–negative patients.

Despite the lack of robust clinical data at present, there is a global consensus that proximity of nasal, oral, and respiratory mucosa to the access areas in skull base surgery subjects neurosurgeons to a higher risk of acquiring COVID-19 infection during surgical procedures.1,5,7,34 Hence, adequate precautions and diagnostic testing are mandatory to reduce the risk of cross-infection. Endonasal procedures pose a significant risk to operating staff, given the high viral load in the upper airway of infected patients.26,46 Use of debriders and drills within the nasal cavity produces droplet aerosols which may be highly contagious. The American Association of Otolaryngology—Head and Neck Surgery (AAO-HNS) recommends deferring endoscopic endonasal procedures unless emergent or until preoperative COVID-19 testing can be performed.1 In patients for whom surgery cannot be deferred, consideration should be given to alternatives to endoscopic surgery: craniotomy (if the frontal sinuses can be avoided) or microscope-based transsphenoidal surgery (submucosal approach and entry to the sella using non–drill techniques).3 Ultrasound surgery should be taken with nasal secretions, and powered air-purifying respirators should be worn during the procedure.34,36 Hence, minimal use of high-speed drills, minimal irrigation while drilling to reduce aerosol generation, avoidance of opening the frontal sinuses and mastoid air cells during transcranial surgery (if feasible), wearing of face shields to reduce direct exposure of conjunctiva to generated aerosols and droplets, preferable use of rongeurs and nibblers in place of drills (wherever feasible), and use of novel techniques are recommended to further reduce
direct contact between the neurosurgeons and operative field aerosols. We have conceptualized the use of a novel microscope-mounted plastic drape covering the operative field (Fig. 3), with built-in slots to insert instruments and operate. Adherence to these basic surgical principles and protocols has ensured safe neurosurgical practice in our department as of the time of this writing.

Postoperative Care

Strict decontamination of the OR is required after surgery. In our setup, the ORs undergo fumigation after each case in COVID-19–suspected and COVID-19–positive patients to ensure minimal risk of cross-infection to subsequent cases. Hospital infectious disease departments may be requested to intermittently perform tests in the OR to check for the presence of viruses. The American Association of Neurological Surgeons/Congress of Neurological Surgeons Tumor Section and Society for Neuro-Oncology recommend shifting patients after simple craniotomies to stepdown units or wards instead of ICUs and to make efforts for early discharge of patients to their homes rather than rehabilitation centers. Additionally, it is recommended that family visits be limited to a strict minimum.

Revamp of Neurosurgical Education

The suspension of elective surgeries at most hospitals has drastically changed the daily schedules of neurosurgical residents, who now find themselves with more free and unstructured time. Maintenance of essential standard medical and surgical education among residents during pandemic conditions is paramount. To ensure that residents have access to ongoing learning opportunities, the department of neurosurgery at the Geneva University Medical Center has introduced daily microsurgery courses in training rooms at the Swiss Foundation for Innovation and Training in Surgery, following adequate social distancing norms. In most hospitals, all in-person conferences such as grand rounds, resident education conferences, and multidisciplinary board meetings have been replaced by video teleconferences and virtual group interactions. There is a substantial current trend for online webinars, supported by various neurosurgical societies, which allows participants from different geographical locations to learn from the experts, ask questions, and occasionally respond to polls. In our department, we have also resorted to online journal clubs, seminars, and other academic activities via webinar portals to ensure resident involvement and active learning. We also have recently conducted a live online cadaveric course for cavernous sinus dissection presented by an international faculty as part of our continuing medical education initiative. Furthermore, we envision the setup of live transmission from our ORs to our trainees via secure web portals in the near future.

Structured Reallocation of Manpower to COVID-19–Designated Areas

A COVID-19 task force (Human Resource Committee) was established under the director of our institute when the global COVID-19 pandemic was declared by the WHO. The purpose of this task force is to optimize and adequately manage the workforce (including residents and faculty) for COVID-19–designated areas to prevent the early burnout of medical personnel and the eventuality of a staff shortage, depending on the number of admitted positive patients and suspected outpatients coming to screening clinics. The departments were divided into multiple categories, primarily based on their degree of current engagement in managing critically ill patients, ranging from clinical departments to pre-/paraclinical departments. Correspondingly, treatment facilities for COVID-19–designated areas were categorized into various levels based on the characteristics of patients being treated, and the management of decision making, which will need to be implemented. Accordingly, a template was created to allocate different categories of residents and faculty to their appropriate levels of COVID-19–designated facility (depending on their clinical exposure to ICUs, high-dependency units, and critically ill patients), if the need arises (Fig. 4). At present, our institute is providing care to more than 750 COVID-19–positive cases overall, including approximately 150 patients requiring assistive ventilation or oxygenation. In addition, hundreds of patients are coming to screening areas daily for COVID-19–suspected cases, with an anticipated increase in these numbers as the pandemic unfolds. Hence, many departments, including neurosurgery, have deployed their personnel in the COVID-19–designated areas. The training module before the deployment includes online video sessions and live demonstrations of correct donning and doffing techniques by the HICC and training for intubation and resuscitation measures by a team appointed by the team leader faculty members of the COVID-19 task force. To ensure that a uniform level of training is devised and delivered, close coordination is paramount between the respective faculty in charge of COVID-19–designated facilities and the nodal officers of the HICC and COVID-19 task force.
Future Trends and Conclusions

In the face of adversity and challenge, global collaborative efforts are underway to tackle the COVID-19 pandemic. Relentless efforts to find better diagnostic tools, optimal treatment options, and preventive vaccines have marked a new era in the history of humanity. The advent of artificial intelligence–based diagnostic tools for COVID-19 could help us diagnose early and facilitate contact tracing to contain this virus.48–50 The potential impact of the antiviral drug remdesivir in treating severe COVID-19 infections has been validated in recent trials.51–54 At the time of this writing, the role of hydroxychloroquine for prophylaxis and as a therapeutic option was still debatable.55–59 Innovative techniques, use of technology, consensus building, and adaptability to new evidence-based guidelines are vital for present-day neurosurgeons to optimize patient care and resident training without jeopardizing one’s own safety.

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