

A Systematic Review on the Impact of the COVID-19 Pandemic on Neurosurgical Practice and Indian Perspective

Abstract

Objective: The study objective was to systematically review the impact of the current pandemic on neurosurgical practice and to find out a safe way of practicing neurosurgery amid the highly infectious patients with COVID-19. **Materials and Methods:** A review of the PubMed and EMBASE databases was performed. The literature was systematically searched using keywords such as “COVID-19” and “Neurosurgery.” **Results:** Among the 425 records, 128 articles were found to be eligible for analysis. These articles described the perspectives of the neurosurgical departments during the pandemic, departmental models, and organizational schemes for triaging emergent and nonemergent neurosurgical cases for the optimal utilization of limited resources, and solutions to continue academic and research activities. Triaging systems help us to optimally utilize the limited resources available. Guidelines have been developed for safe neurosurgical practice and for the continuation of clinical and academic activities during this pandemic by various national and international neurosurgical societies. Key changes in the telemedicine regulatory guidelines would help us to continue to provide neurosurgical care. Videoconferences, online education programs, and webinars could help us to overcome the disadvantages brought upon the neurosurgical education by the social-distancing norms. **Conclusion:** In an unprecedented time like this, no single algorithm is going to clear the ethical dilemma faced by us. Individual patient triage is a way for maintaining our ethical practice and at the same time, for efficiently utilizing the limited resources. As the pandemic progresses, new guidelines and protocols will continue to evolve for better neurosurgical practice.

Keywords: COVID-19, impact, neurosurgery, triage

Introduction

In late December 2019, China detected pneumonia of unknown origin in its Wuhan city, Hubei province. They declared it to the WHO regional office in China on December 31, 2019.^[1] The causative organism was found out to be a novel member of the coronavirus family on January 8, 2020.^[1] The disease became widespread across the globe over the next 2 months. The WHO declared it a pandemic on March 11, 2020, and named the disease COVID-19.^[2,3] The center of the pandemic is now in the USA; South America; and few Asian nations such as India, Iran, and Russia. Many of the European nations have already started flattening of the pandemic curve. The number of cases diagnosed has increased to 12.2 million cases worldwide and 793,802 cases in India as on July 10, 2020.^[4]

As the number of positive cases climbs exponentially, the hospitals and

the overall health-care system have become overwhelmed. The bulk of the hospital beds are dedicated to managing COVID-19-positive and suspected patients. Not only do the clinical works, including outpatient departments (OPDs) and elective surgeries, but also the academic activities have been affected. In this article, we undertook a systematic review of the articles detailing the impact of the current pandemic on neurosurgical practice and tried to find a safe way of practicing neurosurgery among highly infectious patients with COVID-19 disease.

Materials and Methods

We used Preferred Reporting of Items for Systematic Reviews and Meta-Analyses Protocols for literature search.^[5] Medical databases, including PubMed Central (from January 1, 2019, to May 20, 2020) and EMBASE (from January 1, 2019, to

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May 20, 2020) were searched. Search terms, “COVID-19” and “Neurosurgery,” were used for the literature search. We assessed the search result for its relevance on the impact of the current pandemic on neurosurgical practice, academic and clinical training, neurosurgical resource allocation, and methods of triaging neurosurgical cases.

Results

The literature search yielded 425 articles, including original articles, letters to the editor, and editorials. We excluded articles that were concerned with epidemiological and clinical characteristics of COVID-19, impact on other specialties, neurological signs of COVID-19, severe respiratory syndrome, COVID-19 critical care, epidemic control measures, risk factors for COVID-19 infection, and psychological care of dedicated medical staff. Similarly, articles written in languages other than English (two of them) and case reports were excluded. After exclusion, 128 articles were found out to be eligible [Figure 1]. These articles were concerned with the impact of the COVID-19 pandemic on neurosurgical practice; human resources distribution; resource allocation for continuing ethical neurosurgical practice, protocols, and algorithms for neurosurgical case triaging with limited resources; the role of telemedicine in neurosurgical practice; and neurosurgical research and academic activities during this pandemic. Most of these articles were in the form of expert opinions or explaining difficulties faced by the individual institution and their ways of overcoming such difficulties due to this pandemic. The abstract from these studies has been discussed in the following text.

Impact on elective surgeries and triage systems

As the hospitals are flooded with waves of patients with COVID-19 after the pandemic, they started experiencing an acute shortage in hospital beds, ventilators, personal protective equipment (PPE), and, more importantly,

health-care providers. The countries which are facing an exponential growth in the number of COVID-19-positive cases have already reduced or halted the elective surgeries throughout the globe.^[6-9] In a global survey by Jean *et al.*,^[10] it was found that a high prevalence of COVID-19-positive cases and government policy on lockdown of shops and public transport services were responsible for the closure of elective surgeries, and clinics. As the COVID-19 disease started to spread alarmingly in the USA, the American College of Surgeons recommended suspension of all elective surgeries on March 13, 2020, to cope up with the increasing number of patients.^[6] Similarly, many countries in the European Union made recommendations for postponing the elective surgeries.^[7]

Throughout the globe, many institutions have formulated strategies based on the local, regional, and national policies to preserve and optimally utilize the available resources such as hospital beds, ventilators, operation theaters, and PPE.^[11,12] As the number of patients with COVID-19 has been increasing exponentially, hospital resources such as intensive care unit (ICU) beds and ventilators have become sparsely available. Neurosurgical residents and faculties are redeployed to manage the loads of COVID-19 patients. To make use of the limited beds and operation room (OR), developing a triage system and protocols to prioritize neurosurgical cases based on the urgency with which patients need surgical intervention has become mandatory.^[13-17]

Table 1 compares the various triaging systems for emergency and elective neurosurgical procedures followed at many centers. The Centers for Medicare and Medicaid Services (CMS) has provided guidelines for nonemergent, elective medical services. The CMS has recommended a three-tiered framework to prioritize health-care services to those who require emergent or urgent attention.^[11]

Burke *et al.*^[14] formulated a method to utilize the OR service according to the community COVID-19 disease burden. They created a color-coded system (green, yellow, red, and black) to quantify the “surge level” of the disease based on the severity of the viral transmission in the community. OR services are capped as per the color coding of the region. At the green level, all the elective cases are permitted. Similarly, at yellow and red levels, OR service is allowed to work at 75% and 50% of their capacity, respectively. As the number of cases increases, the color-code of the particular region is updated to contend with COVID-19 patient load. They also developed a system based on a “paired coverage model” to manage emergency and semi-emergency neurosurgical cases. In this model, each hospital is covered by two nonoverlapping teams and an alternative pool for substituting those who show symptoms of COVID-19 disease. All the information transfer between the teams is entirely virtual via videoconferencing. This system

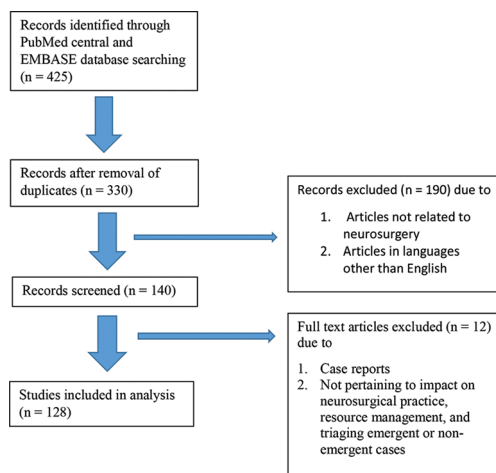


Figure 1: Flow diagram (Preferred Reporting of Items for Systematic Reviews and Meta-Analyses) showing study selection

Table 1: Various systems to triage emergent and nonemergent neurosurgical cases during the COVID-19 pandemic

Triage system by CMS, 2020 ^[12]	ESAS [‡] by ACS, 2020 ^[13]	Arnaout O <i>et al.</i> , 2020 ^[15]	Zacharia BE <i>et al.</i> , 2020 ^[17]
Tier 1 (low-acuity treatment or service)	Tier 1a (low-acuity surgery/healthy patient) Tier 1b (low-acuity surgery/unhealthy patient)	Emergent (within hours) Urgent (hours to days)	Emergent (performed as soon as possible)
Tier 2 (intermediate-acuity treatment or service)*	Tier 2a (intermediate-acuity surgery/healthy patient) Tier 2b (intermediate-acuity surgery/unhealthy patient)	Elective (<6-12 weeks) Elective (>6-12 weeks)	Urgent (performed as soon as possible, 2-7 days)
Tier 3 (high-acuity treatment or service) [†]	Tier 3a (high-acuity surgery/healthy patient) Tier 3b (high-acuity surgery/unhealthy patient)	Cosmetic (indefinite)	Semi-urgent (performed within 1-4 weeks)

*Postponing the treatment can be associated with potential morbidities and should only be considered if no current symptoms; [†]Postponing the treatment is harmful to patient and not recommended; [‡]Tier 1 and 2 can be postponed, and tier 3 should be operated as early as possible. ESAS – Elective Surgery Acuity Scale; CMS – Centers for Medicare and Medicaid services

ensures adequate coverage and minimizes inter-team disease transmission.

Arnaout *et al.*^[15] divided the neurosurgical cases into five categories. Category 1 includes emergency cases which have to be operated or intervened within an hour or two. These cases include traumatic intracranial hematomas such as extradural hematomas, subdural hematomas, intracranial hemorrhage (traumatic or spontaneous) with mass effects, and acute stroke requiring thrombectomy. Category 2 or urgent cases where the intervention is required in hours to days include pituitary apoplexy and tumors with mass effect. This stratification is simple and easy to triage the neurosurgical cases. Similarly, Elective Surgery Acuity Scale, a five-tier classification system, was developed by the American College of Surgeons.^[12]

Zacharia *et al.*^[16] created three neurosurgical case scenarios, namely emergent, urgent, and semi-urgent cases. Emergent cases such as any space-occupying lesions with impending herniation need to be operated as early as possible, and all the patients should be considered as COVID-19 positive. Urgent cases should be operated within a week and include high-grade glioma and tumors with rapidly progressive deficits. Semi-urgent cases, including benign tumors with no or minimal mass effect, can be scheduled in 1–4 weeks' period.

Disease-specific approach

Malignant tumors such as high-grade glioma, solitary brain and spinal metastasis, and any lesion with impending herniation could result in permanent neurological deficits if not operated promptly. Low-grade glioma and other benign tumors such as cerebellopontine angle tumors can be delayed probably for 1–3 months unless the seizures are uncontrolled, or they produce a mass effect, hydrocephalus.^[18,19] Cauda equina syndrome due to any cause should be considered an emergency, and early surgery within hours would be appropriate instead of waiting for the COVID-19 status.^[18] Traumatic spine injuries such as traumatic spinal instabilities, incomplete spinal cord injury with persistent cord compression, or progressive spinal cord injuries require emergency

surgery within 24–48 h.^[20] Patients who require emergency surgeries before the virology results are considered positive patients, and all standard precautions for COVID-19 are strictly followed.^[21]

High-risk procedures

Procedures such as transnasal endoscopic procedures, transoral odontoidectomy, and any procedure that violates mucosa of the paranasal sinuses have been considered high-risk procedures. These procedures generate high load of aerosol-containing viral particles and have higher chances of infection spread to the surgical team.^[22] Similarly, skull-based approaches that require mastoid drilling carry the risk of aerosolization of virus particles. Across the world, many neurosurgical societies recommend against the routine use of transsphenoidal approaches for pituitary tumors during the pandemic.^[23-27] Many advised that the transcranial procedures may be preferred to transnasal transsphenoidal approach. However, sellar–suprasellar tumors without significant visual deficits or hydrocephalus can be scheduled to a later date. In situations such as pituitary apoplexy or acute visual deterioration, early surgery is required for better neurological outcomes.

Many institutions across India and world over have suspended OPDs due to the pandemic except the emergency department.^[3,8,9,17] They have adopted telemedicine strategy, including phone visits and video calls, to fill the gap between the patients and health-care workers.^[9,28] The impact of the current pandemic on neurosurgical education, training, and research is immense and widely reported across the world.^[29-31] Reduced number of elective surgeries, closure of OPDs, redeployment of neurosurgical and research fellows for COVID-19 management, and physical distancing norms have been reported to be the cause for this negative impact.^[30,31] These factors have brought deficits in physical examination, training in the intensive care of pre- and postoperative neurosurgical patients, and hands-on surgical training. Also, across the world, conferences and annual meetings and workshops have been deferred or postponed.^[30,31]

Discussion

Need for reorganization of the health-care system

We are currently experiencing very rapid spread of COVID-19 among our population in India. To combat the current situation, we and other institutes across India are forced to rearrange our hospital system.^[17] We follow a zonal system to triage the patients according to their COVID-19 status. A contaminated zone has been created in a separate section of the hospital building to completely isolate the COVID-19-positive patients from the rest of the areas. This zone handles all the COVID-19-positive cases with dedicated intensive care facilities for severe cases. A semi-contaminated zone is an area where the suspected patients are isolated. Individual accommodation

is followed in contaminated and semi-contaminated zones, and the COVID-19-negative patients are kept in the clean zone. We have created two entry points for receiving the patients. One of them is for trauma- and nontrauma-related emergency cases, and the second one is for nonemergency and follow-up patients. At both entry points, the patients are screened for signs and symptoms of COVID-19 disease, body temperature, and possible exposure to the virus transmission. Nasal and oropharyngeal swabs are collected from all patients for diagnosing COVID-19 disease using reverse transcriptase-polymerase chain reaction. A dedicated OR with negative pressure has been established for COVID-19-positive patients or suspected patients. Having a perioperative checklist helps us to avoid any breach in the protocol [Table 2].

Table 2: Perioperative checklist for neurosurgical procedures

Preoperative	Intraoperative	Postoperative
Priority level of surgery: Emergent/urgent/semi-urgent/semi-elective/ elective	Are surgical and anesthesia team members identified and listed? Yes/no	Are postoperative care givers ready to receive the patients? Yes/no
High-risk procedure for viral transmission: Yes/no	Is OR negative pressure system functioning? Yes/no	If ventilator required, are necessary arrangements made? Yes/no
COVID-19 status of the patient: Negative/suspected/positive	Is PPE available for all members of the team? Yes/no	Is patient on mask while transporting? Yes/no
Conveyed to anesthesia team and OR nursing staff: Yes/no	Are all necessary equipment available? Yes/no Are all high-touch equipment covered with transparent plastic sheets? Yes/no	If OR is decontaminated, whether disinfected with sodium hypochlorite 1000 ppm as per protocol after the procedure? Yes/no
Negative pressure OR: Available/not available	Type of anesthesia: General/regional/awake If regional/awake, is patient on mask during procedure? Yes/no	
Is patient on N95 mask and theater suit? Yes/no	Difficulty in airway: Expected/not expected If expected, is anesthesia team prepared with necessary equipment? Yes/no	
Is itinerary planned? Yes/no	Powered drill system: Required/not required If required, is system set at lower power? Yes/no	
Blood and blood products available: Yes/no	Ultrasonic cavitating devices: Required/not required	
Postoperative care at: Contaminated/semi-contaminated/clean zone	Weaning process: Extubation/elective ventilation	
Availability of bed in the concerned zone: Yes/no	Any breach in the protocol during procedure: Yes/no If yes, mention the details	

PPE – Personal protective equipment; OR – Operating room

Table 3 describes the triage system for elective and emergency cases followed in our institute. In neurosurgical specialty, all the cases are prioritized as elective, semi-elective, semi-urgent, urgent, and emergency [Figure 2]. With this policy, we could effectively triage all patients based on the urgency with which they

require intervention. It helps us to use the limited beds and PPE kits effectively. Whenever possible, urgent cases are closely monitored in the ICU until the COVID-19 status of the patient is available to avoid the stress of performing long procedures in PPE. Postoperatively, those patients who are positive for COVID-19 are monitored at

Table 3: Triage of emergent and nonemergent neurosurgical cases in our institute

Priority level	Waiting period between diagnosis and surgery	Examples	Action plan
Emergency	Within hours	Traumatic intracranial hematomas, cauda equina syndrome, acute hydrocephalus, any lesion with impending herniations, mechanical thrombectomy for acute stroke	Emergency surgery
Urgent	24-72 h	Aneurysmal subarachnoid hemorrhage, tumors with mass effect, cerebral abscess, pituitary apoplexy, spine injuries	Emergency surgery/if possible, wait for the COVID-19 status
Semi urgent	1-2 weeks	Malignant tumors, tumors with progressive visual deterioration	Plan as per ICU bed/blood/workforce availability
Semi-elective	2-4 weeks	Large meningiomas, degenerative spinal diseases with pain or myeloradiculopathy	Postpone if symptoms are minimal or Plan as per ICU bed/blood/ man power availability
Elective	More than a month	Cranioplasty, epilepsy, and functional neurosurgeries, benign tumors with drug controlled seizures	Postpone indefinitely till pandemic control

ICU – Intensive care unit

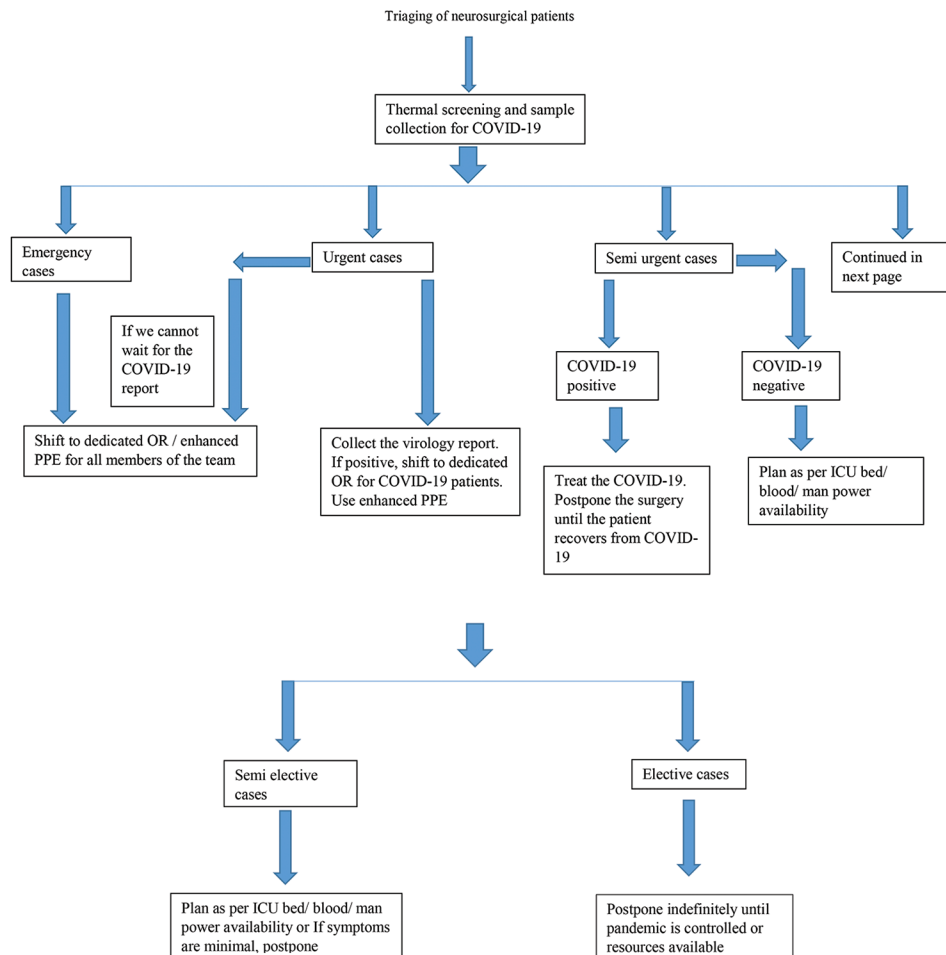


Figure 2: Flow diagram showing the steps of triaging emergent and nonemergent neurosurgical cases

the contamination zone along with the infectious disease team. COVID-19-negative patients are shifted back to the neurosurgical wards or ICU in the clean zone.

Residents, faculties, and nursing officers need to be given rapid training on airway management, ventilator management, arterial blood gas analysis, electrocardiogram interpretation, proper methods of donning and doffing of the PPE, and sterilization methods. Others, including housekeeping and other technical staff, should also be educated about the standard practices that should be followed to avoid virus transmission among the hospital workers. Nonoverlapping teams of residents and faculties should manage all the zones on rotation for a given period. A separate reserve team should be identified to replace the persons who may require quarantine during patient care. Interaction between the teams should be strictly maintained via phone calls and videoconferencing.

Perioperative strategies

At the point of initial contact in the hospital, all patients should be screened for symptoms such as unexplained fever, headache, chills, cough, breathing difficulties, myalgia, sore throat, anosmia, and ageusia within the last 2 weeks. They should also be assessed for the possible exposure to someone diagnosed with COVID-19 in the past 14 days.^[32] One should remember that only 44% of patients with COVID-19 disease had a fever in a previous study.^[33] A significant number of patients with COVID-19 disease can be asymptomatic, and the reported incidence varies from 1.6% to 56.5%.^[34] It is mandatory to test all patients who require hospitalization for COVID-19.

The sensitivity and specificity of any test to detect SARS-CoV-2 depend on the type of sample, the sampling technique, the tests performed, and the phase of the disease course during the testing. The reported sensitivity of SARS-CoV-2 testing may vary from 70% to 90%.^[35] Nucleic acid amplification testing for the detection of viral ribonucleic acid is the investigation of choice for preoperative diagnosis.^[32] The American Society of Anesthesiologists and Anesthesia Patient Safety Foundation have given perioperative COVID-19 testing guidelines for elective surgery.^[36,37] For all elective surgeries, two negative nasopharyngeal swabs alone or with oropharyngeal swabs 24–48 h apart should be mandatory to avoid false-negative reports.^[32,36,37] Computed tomography chest is not useful in the preoperative evaluation of COVID-19 status in asymptomatic patients. Hence, it is not recommended for screening before elective surgery. If a patient tests positive for SARS-CoV-2, elective surgical procedures should be delayed. As per the Centers for Disease Control and Prevention recommendation, a patient can be infectious until resolution of fever and respiratory symptoms and two negative SARS-CoV-2 tests more than 24 h apart or the resolution of fever and respiratory symptoms for at least 72 h and at least 10 days since initial symptom presentation.^[32]

Aerosolized droplets with viable SARS-CoV-2 can remain suspended for 3 h. The estimated median half-life of SARS-CoV-2 can be approximately 5.6 and 6.8 h on stainless steel and plastic surfaces, respectively.^[22] Nasopharyngeal and oropharyngeal mucosa carry the bulk of the virus load. Any procedure violating these mucosae can produce droplets and aerosols, which can permeate through the entire OR.^[23] Such procedures carry a high risk for disease spread to the entire surgical team. The surgical team should exercise the following precautions to minimize aerosol generation and to avoid infection spread while operating on COVID-19-definite or suspected patients.

- OR personnel should be kept minimum, and a single surgeon is preferred as far as possible
- All the personnel in the OR are required to use enhanced PPE (N95 mask/powerful air-purifying respirator mask, full body and head cover, face shields/eye protection glasses, surgical suits, and double gloves)
- Use of electrocautery and powered drills and ultrasonic cavitating devices intraoperatively should be avoided as they generate excessive aerosols and help to disperse the viral particles.^[23] If the use of powered tools is unavoidable, they should be used at lower power with gentle saline irrigation. Drilling areas can be isolated with transparent adhesives or tents. Wide-bore suction can be used to reduce the free particulate matter and aerosol.^[38]
- Nasal mucosal violation should be kept minimum. Routine stripping of the sphenoid mucosa should be avoided in transsphenoidal approaches
- The operative team should have a “quick-in” and “quick-out” strategy to reduce the exposure to viral load.

Resuming outpatient departments and academic activities

Telemedicine plays an immense role in continuing the patient care amidst the disadvantages brought by the lockdown and social-distancing measures. Health-care professionals can use any telemedicine tool suitable for carrying out technology-based patient consultation (e.g., telephone; video; devices connected over local area network, wide area network, Internet; mobile or landline phones; chat platforms such as WhatsApp and Facebook Messenger; and mobile apps, or internet-based digital platforms for telemedicine, or data transmission systems such as Skype/email/fax).^[39]

The current pandemic has brought several critical changes in the pre-COVID-19 telemedicine regulatory guidelines. Insurance coverage for telehealth visits, allowing the use of non-Health Insurance Portability and Accountability Act-compliant applications, and the ability to prescribe Schedules II to V controlled substances to patients seen using telemedicine communication are some of them.^[28,39] When telemedicine is properly utilized, we would be able to

briefly evaluate the patients' neurological status and review the images. Thus, a provisional diagnosis and management plan can be arrived at without the need for multiple visits. Patients who require urgent surgical care can be triaged even without personal contact. However, telemedicine is still in the early stage of development in India despite the success of various projects such as the Indian Council of Medical Research-AROGYASREE, National e-Health Authority, and village resource centers.^[40]

Academic institutions have adopted many technologies which have made video conferencing a new normal for the continuation of academic activities such as journal clubs, seminars, and operative video teaching sessions, which also allows for the interaction between the patient care teams.^[41-43] Simulation technologies and virtual reality technologies such as Microsoft HoloLens (Microsoft Corporation, Redmond, WA, USA) and Oculus Rift (Facebook Technologies, West Menlo Park, CA, USA) can overcome the decline in the operative experience. Online education programs and operative video atlas developed by national and international neurosurgical societies could become an integral part of neurosurgical training during this pandemic.^[44,45]

The Congress of Neurological Surgeons has developed web-based education programs such as "grand round webinars" and live interactive "virtual visiting professor sessions."^[44] Neuroanatomy online resources such as "the Rhoton Collection" and "virtual operating room" under the Neurosurgical Atlas have been made available by the American Association of Neurological Surgeons (AANS).^[45] Online conferences and webinars have gained widespread recognition and are helpful in knowledge sharing without geographical boundaries. Under the Neurological Society of India, neurosurgical anatomy webinar series are conducted via Zoom meeting where the neurosurgical experts across the world are invited to take part in the educational program.

Way forward

Although it is straightforward in many cases to decide the priority level of the intervention, there are gray areas where the decision to postpone the surgery is difficult to make, especially if the natural course of the disease is unpredictable. Before deciding to postpone surgery for a patient, one should answer the following questions:

1. How long is this pandemic going to last?
2. Can the patient have a disease course without affecting his/her functional status until the resources will be available?
3. What are the chances of incurring permanent neurological deficits if the proposed treatment is postponed?
4. How severe would the neurological deficits be?
5. Is there a possibility of death if the intervention is postponed?

The decision to operate or to delay the surgery is confounded by the limited availability of hospital beds, ICU admission, and ventilators. It cannot be based on a "first to come and first to be served" policy or lottery system.^[46] Factors such as the age of the patient, comorbid diseases, the risk for severe postoperative neurological deficits, the need for prolonged ventilatory care after surgery, and the life expectancy of the patient after the surgery come into play when the resources are limited. An ethical way for a health-care provider is to triage individually, and the treating physician has the ultimate responsibility to treat each patient tailored according to the natural course of the disease.

There are no established guidelines for resuming elective surgeries and OPDs. Elective surgeries can be started if the incidence of new COVID-19 cases shows a consistent decline for at least 2 weeks.^[47,48] The hospital resources should be adequate to restart the elective work without resorting to the crisis phase. One should be cautious that premature relaxation of restriction could lead to a second wave of infection. Guidelines and regulations for COVID-19 control should be maintained to prevent new infection recurrence during the transition period.

Conclusion

Standard protocols have to be formulated to utilize limited resources and preserve human resources efficiently. Strict adherence to the departmental and hospital policies, efficient and timely interaction, and coordination between the various specialties are essential for better patient care during this pandemic. In an unprecedented time like this, no single algorithm will clear the ethical dilemma faced by us. Individual patient triage based on the natural course of each disease is a better way for maintaining our ethical practice and, at the same time, for efficiently utilizing the limited resources. We must make use of various technologies and web-based educational materials to continue the clinical, academic, and research activities to overcome the disadvantages brought by the social-distancing norms. As the pandemic progresses, new guidelines and protocols will continue to evolve for better neurosurgical practice.

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Conflicts of interest

There are no conflicts of interest.

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