Analysis of Neurosurgical Cases Before and During the Coronavirus Disease 2019 Pandemic from a Tertiary-Care Centre in India

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■ OBJECTIVE: **We present the unique administrative issues as well as specific patient-related and surgeon-related challenges and solutions implemented while treating neurosurgical patients during the coronavirus disease 2019 (COVID-19) pandemic vis-à-vis pre-COVID-19 times at our tertiary-care center.**

■ METHODS: **This is a retrospective study comparing the outcome of the neurosurgical patients treated from the beginning of lockdown in India on March 25, 2020 to November 30, 2020 with that of same period in the previous year, 2019.**

■ RESULTS: **There were 687 neurosurgery admissions during the study period compared with 2550 admissions in 2019. The total number of surgeries performed in neurosurgery also showed a similar trend, with only 654 surgeries in 2020 compared with 3165 surgeries in 2019. During COVID-19 times, 474 patients were operated on including both trauma and nontrauma cases. Of the 50 patients with suspected/indeterminate COVID-19 who were operated on, 5 turned out to be positive for COVID-19. Significant differences were seen in the mortality ($P < 0.01$) and morbidity ($P < 0.01$) among patients with trauma on comparing COVID and pre-COVID periods. Similarly, a significant difference was observed in the mortality ($P < 0.001$) and morbidity ($P < 0.001$) in patients who did not have trauma.**

■ CONCLUSIONS: **The higher mortality and morbidity during the COVID pandemic is primarily attributable to poorer baseline clinical status. Our experience from this COVID period might not only help us in tackling subsequent waves but also help other institutions in the developing world to be better prepared for similar circumstances.**

INTRODUCTION

The severe acute respiratory disease syndrome coronavirus 2, also known as coronavirus disease 2019 (COVID-19), has exacted many adverse effects on the global health care system and has thus posed difficult challenges for optimal health care delivery in the fragile health systems of many developing countries such as India. An increasing proportion of health care resources had to be compulsively dedicated to treating patients with COVID-19 as the pandemic intensified in our nation. Akin to other medical specialties, a paradigm shift was inevitable in the neurosurgical discipline, with channelization of hospital resources and workforce to emergency care at the cost of outpatient and inpatient services.[1-9] Our tertiary-care referral center has a busy neurosurgical service. Before the pandemic began, we were treating about 130,000 patients on an outpatient basis and performing around 6000 surgeries annually.[10] We had to curtail elective surgical procedures and outpatient services because of the nationwide lockdown. Performing surgery on admitted patients was fraught with clinical and administrative challenges. In this study, we attempt to highlight the unique administrative issues faced as well as specific patient-related and

Key words
- Challenges
- COVID-19
- Lockdown
- Lower-middle income countries
- Neurosurgery
- Pandemic

Abbreviations and Acronyms
COVID-19: Coronavirus disease 2019
ICU: Intensive care unit
OR: Operating room
PPE: Personal protective equipment
RT-PCR: Reverse transcriptase polymerase chain reaction

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surgeon-related issues in this large neurosurgical service in a developing country. We also highlight the solutions implemented while treating >200 patients surgically during this pandemic phase, which we believe will be helpful in the future as well.

METHODS

This retrospective cohort study was conducted at the apex (tertiary) care institute of India after obtaining appropriate ethical clearance (IEC/977/9/2020). Data of the neurosurgical patients treated from the beginning of lockdown in India on March 25, 2020 to November 30, 2020 were obtained from the computed database of our hospital. Records of patients who were treated at our center during the same period in 2019 were retrieved for comparative analysis. Two groups were thus created (COVID-19 and pre-COVID-19) and data related to demographic profile, diagnosis (cranial or spinal, trauma or nontrauma), management (type of intervention [surgery or conservative], type of procedure), outcomes (in-hospital mortality, complications, hospital stay), and so on were compared between the 2 groups. Mean year of experience for the operating surgeon was calculated according to the number of years spent as a specialist neurosurgeon.

All admissions in both groups were categorized based on cause (trauma and nontrauma), management strategy (surgical and nonsurgical), and pathologic diagnosis (neoplastic, vascular, infectious, hydrocephalus, peripheral nerve, spine diseases). Patients younger than 18 years were included in the pediatric age group. The outcome was assessed in terms of morbidity (operative or nonoperative complications) and mortality. For the purposes of this study, morbidity was defined as any adverse event that prolonged the hospital stay or added significantly to the post-discharge medical care needed or that resulted in a temporary or permanent neurologic deficit. The data collected were entered in Microsoft Excel (Microsoft, Redmond, Washington, USA) and statistical analysis was performed using SPSS version 20 (IBM Corp., Armonk, New York, USA). A χ^2 test was used to compare the categorical data. A P value <0.05 was considered as significant. Graphic representation in the form of flowcharts was prepared using Microsoft Office Powerpoint 2016 and R Studio (RStudio Inc., Boston, Massachusetts, USA).

RESULTS

We treated 687 admissions under neurosurgery this year during the study period compared with 2550 admissions in 2019. The total number of surgeries performed under neurosurgery (elective, semiemergent, and emergent) also showed a similar trend of much reduced neurosurgical workload, with only 654 surgeries in 2020 compared with 3165 surgeries in 2019. Of a total of 687 patients, 143 (20.8%) belonged to the pediatric age group in 2020 compared with 23.3% in 2019. This difference is primarily caused by the difference in the number of nonemergent surgeries, which was 185 (28.3%) in 2020 and 2169 (68.5%) in 2019. Although the proportion of emergency surgeries was higher in 2020 (72% vs. 32%), the number of emergency surgeries was lower in 2020 (469 vs. 996). The number of patients who underwent Gamma Knife radiosurgery (Elekta, Stockholm, Sweden) was also less, with only 102 patients (mostly metastases or arteriovenous malformations) in 2020 compared with 439 patients in 2019. Our bed strength was reduced to about a third (69 of 173) and similarly, only one third (3 of 9) operating rooms (ORs) were functional during the pandemic.

Most patients were tested for COVID-19 before surgery but in certain emergent scenarios, patients were taken up for surgery with adequate precautions before the results were available; 50 such patients with suspected/indeterminate COVID-19 were operated on. Of these 50 patients, 5 turned out to be positive for COVID-19 and were shifted to the COVID-19-designated facility. Seven patients tested positive in the postoperative period after testing negative at the time of admission. None of the patients in emergency triage who were found to be COVID-19 positive (63 patients) required emergent surgery. These findings are summarized in Tables 1 and 2.

Outpatient Services

During the study period in 2020, we treated 274 patients via teleconsultation, whereas during the same time in 2019, we had outpatient department visits from 12,222 patients. The comparison of the patients consulted from different states is shown in Figure 1.

Management Strategy

The distribution of causes among the admitted patients was different between 2019 and 2020, as summarized in Figure 2. The management strategies were also changed during this period. For benign causes such as vestibular schwannoma, in which the patient presented with emergent manifestations of hydrocephalus, it was observed that a cerebrospinal fluid diversion procedure was preferably performed initially as a temporary solution to the crisis during the increase of COVID-19 cases in our state. Definitive surgery was deferred for a later date in such cases, which is not our usual protocol. Patients during this period were admitted mainly through the emergency department initially, whereas during the first stage after lockdown, few admissions were made through outpatient clinics based on urgency of symptoms and existing waiting list. Admissions were screened, triaged, and treated by on-duty consultants in conjunction with 2 senior professors of the respective units.

Outcomes—Morbidity and Mortality

A significant difference was seen in mortality among patients with trauma: 18.8% (64 of 341 patients) in 2020 compared with 12.9% (193 of 1491 patients) in 2019 ($P < 0.01$). Similarly, a significant difference was observed in the mortality in patients who did not have trauma: 19.8% in 2020 (72 of 364 patients) compared with 5.3% in 2019 (56 of 1059 patients) ($P < 0.001$).

A significant difference was seen in morbidity in terms of the complication rate among patients with trauma: 19.4% (66 of 341 patients) in 2020 compared with 12.9% (193 of 1491 patients) in 2019 ($P < 0.01$). However, a significant difference was observed in the morbidity among patients who did not have trauma: 20.3% in 2020 (74 of 364 patients) compared with 5.3% in 2019 (56 of 1059 patients) ($P < 0.001$). Patients with traumatic brain injury had a reduced duration of hospital stay in 2020 compared with 2019 (10.2 vs. 12.8 days).

On categorizing according to the treatment, no significant differences were seen in the mortality between the 2 periods in the surgically managed patients with trauma ($P = 0.17$). However,

Table 1. Summary of the Comparison Between Characteristics of Neurosurgery Cases Treated at Our Center Between March 24 and November 30 in 2019 and 2020

Characteristic	2020	2019
Number of patients seen in outpatient department	3373	24759
Number of patients admitted (total)	687	2550
Number of surgeries (total)	654	3165
Number of nonemergent surgeries (planned at least 1 day before)	185	2169
Number of emergency surgeries	469	996
Shifting to incision time (minutes)	78.4 ± 12.9	51.5 ± 9.5
Number of surgeries for patients with trauma		
Cranial trauma	157	493
Spinal trauma	38	146
Peripheral nerve injury	0	66
Number of surgeries for cranial tumor		
Intra-axial tumors	38	344
Pituitary tumors	12	58
Transnasal	10	48
Transcranial	2	10
Extra-axial tumors (e.g., VS)	17	57
Dural-based tumors	28	99
Posterior fossa tumors	29	32
Intraventricular tumors	6	27
High-grade tumors	36	16
Benign tumors	4	14
Number of surgeries for others		
Hydrocephalus		
Shunt	92	232
Endoscopic third ventriculostomy	2	16
Long tunnel external ventricular drainage	15	58
Tracheostomy	57	88
Wound re-exploration	7	32
Number of surgeries for vascular		
Aneurysm	31	35
AVM	11	19
Mean age of patients (years)		
Trauma	32.6	31.7
Nontrauma	34.4	32.9
Mean duration of hospital stay (days)		
Trauma	10.2	12.8
Nontrauma	13.4	12.1
In-hospital mortality (%)		
Trauma	64	193
Nontrauma	72	56
Morbidity (new-onset deficit, meningitis, or fall in Glasgow Coma Scale score by 1) (%)		
Trauma	66	193
Nontrauma	74	56
Gamma Knife radiosurgery	102	439
AVM	29	93
Meningioma	32	104
Pituitary adenoma	10	66
Metastasis	5	12
VS	22	125
Trigeminal neuralgia	1	8
Other benign tumor	3	31

Values are number except where indicated otherwise.
VS, vestibular schwannoma; AVM, arteriovenous malformation.

there was a significant difference in mortality between the conservatively managed patients with trauma (45.2% in 2020 compared with 14.9% in 2019; $P < 0.001$), conservatively managed patients who did not have trauma (53.7% in 2020 compared with 10.6% in 2019; $P < 0.001$) and surgically managed patients who did not have trauma (12.9% in 2020 compared with 4.9% in 2020; $P < 0.001$). The comparison of management and outcomes of patients in 2019 and 2020 admitted to neurosurgery at our center is summarized in **Figure 2** and **Table 1**.

DISCUSSION

On March 24, 2020, a nationwide lockdown was announced in India. Considering the population of India, which is around 1.3 billion, it is by far the largest lockdown in human history.[11] Although there is uniformity of guidelines worldwide irrespective of financial status of countries, lower-middle-income countries have significantly fewer hospital beds, intensive care unit (ICU) beds, ventilators, and doctor/population ratios. This deficiency has put significantly more strain on the health care system during COVID times. With already limited resources being diverted for COVID management, the non-COVID routine and emergent services are directly affected. Thus, the challenges and solutions for lower-middle-income countries are different both qualitatively and quantitatively. Therefore, this lockdown was bound to affect the already strained health infrastructure of India. Impact on neurosurgery can be gauged from the fact that our center, which is otherwise extremely busy in terms of volume of patient flow, had to significantly curtail all elective admissions and outpatient services. Compared with 2019, a decrease of around 73% in surgical procedures and a drastic 97% decrease in

Table 2. Summary of the Comparison Between Resource and Infrastructure Allocation at Our Center Between March and June in 2019 and 2020

	2019	2020 (after Lockdown)
Number of beds in neurosurgery (inclusive of trauma)	173	69
Number of residents posted in neurosurgery	52	14
Number of operation rooms used for neurosurgical procedures in parallel	9	2 (+1 reserved for dire emergency)
Number of neuroanesthesia residents and consultants	15+30	11+20 (4+10 posted in COVID-designated wards)
Number of consultants in neurosurgery	25	22 (2 posted in COVID wards +1 posted for neurosurgical patients admitted in COVID facility)
Number of cases operated free of cost	7	48
Package amount collected (U.S. $)	1,916,487	534,450

outpatient services were observed during the study period. However, we were determined as well as prepared to treat the neurosurgical cases as needed. The total number of surgeries performed increased even in the face of increasing numbers of cases of COVID-19 as shown by Figure 3. We had to quickly adapt to the changing times and find solutions to the unprecedented challenges that we were facing.

Closure of Trauma Center and Creation of Trauma Unit in Main Neurosurgery Building

With the increasing number of COVID-19 cases in the country, there was a need for dedicated facilities with focused medical teams, triage protocols, and infrastructure reorganization. Preempting a rapid surge in the number of cases, 2 of our satellite facilities (the National Cancer Institute and Jai Prakash Narayan Apex Trauma Center) were converted into COVID-19-designated hospitals, to create >1000 beds for patients with COVID-19. This decision was inspired from the model implemented in the Lombardy region in Italy, where most peripheral neurosurgical facilities were converted to COVID-19-dedicated facilities, with the exception of a few large neurosurgical facilities, in which emergent neurosurgical patients were treated.[12,13] The decision to close the Jai Prakash Narayan Apex Trauma Center meant that 70 patients admitted to neurosurgery there had to be accommodated in our main block (neurosciences center), which, under normal circumstances, is only for patients who do not have trauma. We had a total of 173 beds including the satellite centers in the pre-COVID-19 era, which were reduced to 69 beds after considering social distancing norms (Table 2). Further, we had to be prepared for incoming patients with neurotrauma, although they were expected to be fewer than usual.[14] This goal was achieved by halting all new admissions and expediting the discharge of already admitted patients. Additional of ventilators were procured from the trauma center, as well as new purchases being made for extremely sick transferred patients. Similarly, a trauma emergency bay was recreated at the suspended outpatient clinics appointment area as a temporary solution to the crisis. Conversion of existing infrastructure into an infectious diseases hospital occasionally is the only option for many hospitals. However, this option is not without collateral damage to patients who did not have COVID-19 who would earlier have been treated at these facilities. Therefore, development of new infrastructure, or identification of a facility in which less emergent patients (unlike trauma or cancer) are treated, should be considered for treating COVID or any such similar disease outbreaks in future.

Workforce Reallocation—Posting of Neurosurgeons

After the creation of COVID-19-dedicated facilities, both residents and faculty from the department of neurosurgery were posted in these facilities to assist in critical care (nonneurosurgical) management of COVID-19-positive patients. Because this team was on the intensive care roster and not on the neurosurgery roster, separate attendings and residents were posted to take care of any COVID-19-positive patients who primarily had neurosurgical diseases. All the residents and faculty posted in the main neurosurgical block (non-COVID-19 facility) were divided into 3 teams based on the modification of the paired-coverage model originally proposed by Burke et al.[15] and implemented by many centers in the developed world.[16-18] Each team managed the center for 1 week, with the other 2 teams in quarantine for 2 weeks. Even within each team, a minimal possible number of residents were deployed at various stations to minimize exposure. As the lockdown began to be lifted in our country, we reorganized our teams into our usual 2 units with further subdivision into A and B subunits to improve the work efficiency (Figure 4). Based on our experience, we do not recommend posting of the most senior residents in COVID wards, because they are deprived of necessary hands-on exposure in neurosurgery. In our opinion, neurosurgical residents in the initial part of their training years are easily able to adapt to the new situation and on their return from their COVID posting are able to make up for their lost time by working harder to obtain the hands-on exposure in neurosurgery.[7]

Issues Related to the ORs

We had 9 ORs (7 in the elective block and 2 in the trauma center), which used to run in parallel for neurosurgical patients. Trauma center ORs became out of bounds for routine neurosurgical services after conversion to a COVID-19 facility. Of the remaining 7 ORs, 4 could be made functional, 2 were converted into donning and doffing areas for streamlining the movement of OR staff and reducing risk of cross-infection, whereas the seventh OR, which was an intraoperative magnetic resonance imaging suite, was not used because of issues related to sterilization. Of these 4 ORs, initially 2 and then 3 could be used in parallel because of the

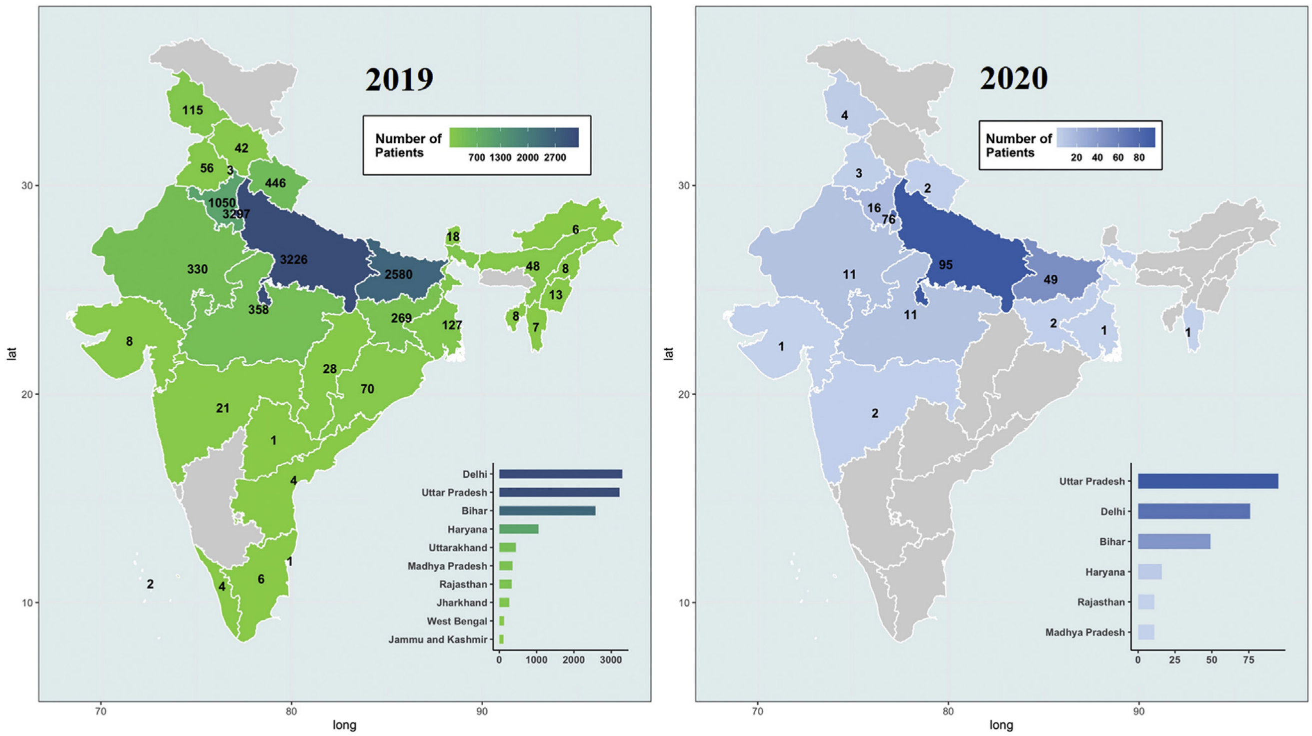
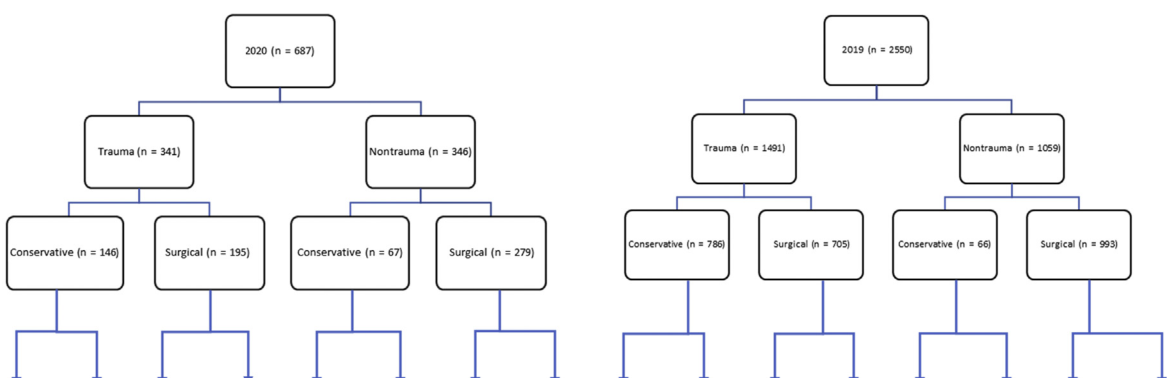


Figure 1. Comparative analysis of state wise distribution of outpatient services between 2019and teleconsultations in 2020.

paucity of neuroanesthesia team members, because 40% of the workforce was shifted to the COVID-19 hospital. The induction time also increased significantly during COVID-19 times by around 40 minutes as a result of the additional COVID-19-related precautions. ORs were modified to have negative pressure ventilation for patients with suspected/indeterminate COVID-19 who required



Diagnosis	Discharge	Death	Discharge	Death	Discharge	Death	Discharge	Death	Discharge	Death	Discharge	Death	Discharge	Death	Discharge	Death
Infection	14	3	8	0	7	1	11	0	5	0	17	0	2	0	7	0
Vascular	0	0	0	0	7	4	45	8	0	0	0	0	2	4	57	9
Hematomas	96	33	139	27	2	5	55	10	594	96	398	66	5	3	70	12
Tumors	0	0	0	0	14	8	128	14	0	0	0	0	34	0	604	28
HCP	0	0	13	0	0	0	0	0	4	0	12	0	4	0	4	0
Spine	0	0	37	1	18	18	4	4	66	21	136	10	12	0	196	0
Peripheral Nerve	0	0	0	0	0	0	0	0	0	0	66	0	0	0	6	0

Figure 2. Flowchart showing the comparison of management and outcomes of patients admitted to neurosurgery in 2019 and 2020. HCP, hydrocephalus.

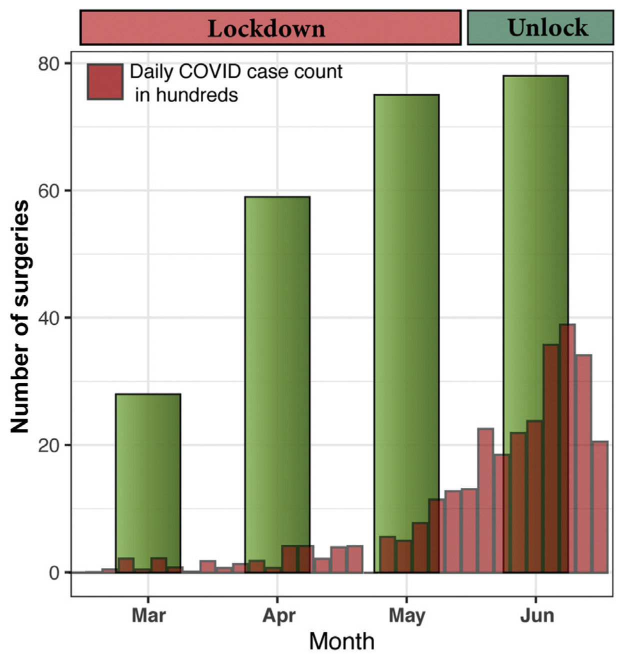


Figure 3. Monthly distribution of surgeries performed at our center vis-à-vis the total number of new COVID-19 cases encountered daily.

emergency surgery and were waiting for the COVID-19 test results, as has been recommended by several investigators.[19-21] The various solutions implemented for infrastructure-related challenges are summarized in **Figure 5A**.

Medicolegal Challenges and Need for COVID-19-specific Consent

Patients or caregivers could have contracted the disease from other staff or patients while in hospital, with a possibility of vice versa also being true. Increased mortality and morbidity are also reported in COVID-19 neurosurgical cases.[1,22] Because of this situation, informed COVID-19-specific consent was obtained, which helped patients and caregivers to understand the risks and prognosis (**Supplementary File 1**).

Challenges Related to Preoperative COVID-19 Testing

Preoperative testing for COVID-19 was made mandatory at our institute. During the initial part of lockdown, availability of reverse transcriptase polymerase chain reaction (RT-PCR) kits was limited because of a sudden surge in requirement and limited supply. As the testing capacity was ramped up, all semiemergency preoperative patients mandatorily underwent gold-standard RT-PCR test during routine hours. Beyond routine hours, emergency patients underwent cartridge-based nucleic acid amplification testing or TrueNAT (Molbio Diagnostics Pvt. Ltd., Hyderabad, India) testing before admission. Reports of these tests can be made available within 3 hours. In cases of dire lifesaving emergency, the patient's sample for COVID-19 is sent and surgery is performed with level III personal protective equipment (PPE), which constitutes a full protective coverall (impermeable to aerosols) worn inside a surgical gown, N95 masks, protective eyewear (goggles with face shield), shoe covers, and double surgical gloves. These patients are later shifted to an ICU for patients whose COVID-19 reports are pending.

Challenges During Surgery in Operating with PPE

As per the protocol of our institute, level II PPE (i.e., inner coverall suits, N95 masks, goggles/face-screen, and outer surgical gown) is to be used for any neurosurgical procedure. In the initial part of our experience, we were unclear about the risk for virus transmission through aerosol-generating procedures performed outside the sinonasal tract (e.g., high-speed drilling during craniotomy). Further, despite the high specificity of RT-PCR tests, the sensitivity in the field was affected by sampling errors. Hence, full PPE (level II/III) use was recommended for all procedures as a precautionary measure. Despite viral RNA detection in a varying proportion of COVID-infected patients, the risk of viral transmission to the surgeon through aerosol-generating procedures has been inexplicably low.[23] Thus, full PPEs for COVID-negative patients were abandoned because the risk perception was not commensurate to the inconvenience of PPE use in prolonged neurosurgical operations. We realized that the use of PPE reduced dexterity, comfort, and visualization. Surgeons had difficulty in performing surgery for more than 3–4 hours at a stretch. Thus, many surgical procedures such as excision of acoustic schwannoma, aneurysmal clippings, and long segment spinal fixations were performed by 2 teams. Each team had 1 attending consultant and 1 resident and they worked in 3-hour-long to 4-hour-long shifts. This strategy was deemed necessary to also decrease exposure of the team to a confined and potentially unsafe environment and ensure good patient outcome.

To improve comfort, engineering interventions with air conditioning helped in decreasing temperature and >6 times air exchange per hour. Visualization was improved by use of endoscopy or exoscopy wherever it was possible. In our morbidity and mortality meets, few cases were discussed because of an unexpected turn of events. We realized that operating in PPE is fraught with challenges for both the anesthesia and neurosurgical teams.

Challenges in Postoperative Management and Critical Care Management

Patients who had undergone RT-PCR testing preoperatively and were found negative were managed in a non-COVID-19 ICU. Level II PPE was used by staff, who worked on an 8-hourly regular shift basis. Staff were sensitized to keep a close watch for symptoms of influenzalike illness and severe acute respiratory infections. All suspected patients underwent repeat RT-PCR testing for COVID-19 as per the advice of the hospital infection control committee.

Patients who underwent surgical procedures before their RT-PCR report for COVID-19 could be made available or patients who were admitted from casualty because of life-threatening emergencies such as an extradural hematoma pending their COVID-19 report were managed in a separate ICU, where patients were allowed only on alternate beds to maintain distance. Staff in this ICU were instructed to wear level III PPE. Six-hourly shifts of health care workers in this ICU were used to maintain staff comfort and decrease exposure. The increased number of shift

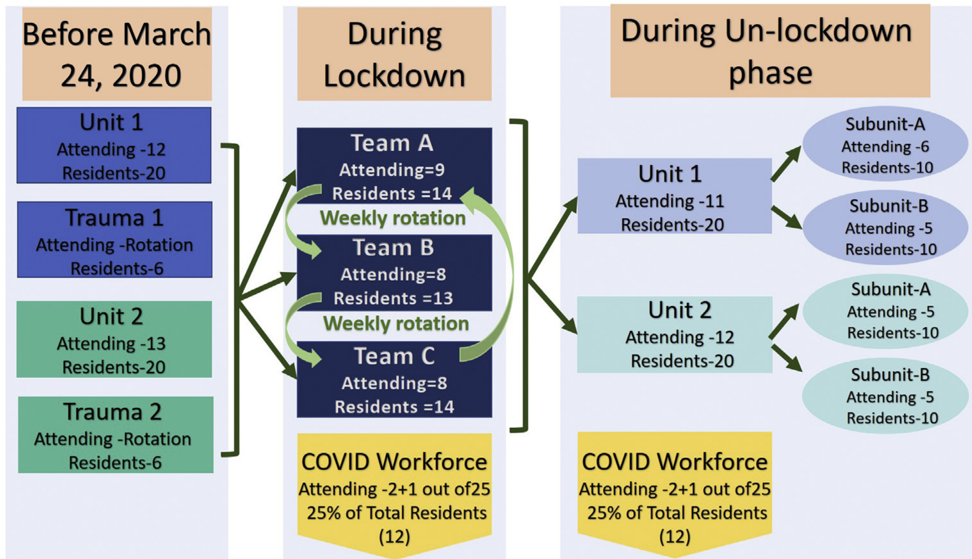


Figure 4. Changes in the workforce allocation during and after lifting of lockdown.

duties required frequent travel for our staff, which was difficult during the lockdown phase.

Surgical Outcomes During COVID-19 Pandemic

We do not believe that the higher mortality of patients who did not have trauma who were operated on during the study period ($P < 0.001$) can be attributed to COVID-19 infection per se. It can be explained on the basis of the fact that we have operated on primarily emergency and semiemergency patients during the study period. These patients were consequently sicker preoperatively compared with the patients operated on in 2019, when most surgery was elective. Other plausible reasons that are directly attributable to COVID-19 could be compromised surgical finesse as a result of the PPE, limited availability of blood products, difficulty in performing awake surgery, use of regular neuro-monitoring, and working in shifts wherein the change in operating teams can lead to disorientation. However, the most plausible explanation seems to be the difference in the baseline clinical status of the patients because only patients with large tumors were operated on during the COVID time. Moreover, no degenerative spine surgeries were performed. This explanation is also proved by the fact that there was no difference in mortality observed in trauma patients (operated or conservatively treated) and patients who did not have trauma managed conservatively during the study period vis-à-vis the 2019 patient cohort group ($P = 0.26$). This finding shows that optimal care could be delivered despite the tremendous challenges involved. The solutions related to surgical challenges are summarized in Figure 5B.

Financial Constraints for Neurosurgical Procedures

The cost of surgery at our public sector hospital ranges from U.S. $25—$500, depending on the type of procedure. As a result of the financial crunch caused by the pandemic, many families lost their livelihoods and because of logistic issues could not arrange for surgical expenses. Twenty-five patients were treated free of cost in the study period compared with 4 in 2019. After discharge, many patients were also provided with temporary accommodation at one of our outsource health facilities until they could arrange transport services, which was difficult because of lockdown. The total amount of money collected for surgery during the study period was around INR 16 million, which is around 60% less compared with the records from the previous year. Despite this major shortfall, no disruption in the supply chain of medicines or equipment was experienced.

Outpatient Services

During lockdown, all the physical outpatient services were temporarily halted. Considering the massive volume of new as well as follow-up patients that our outpatient department used to treat during ordinary times, this situation created a huge void in patient management. We started teleconsultation to mitigate the consequent deficiency in outpatient services because it has shown good satisfaction in recent studies.[10,24-26] The huge difference between demand and supply that we observed is reiterated in other studies.[7,27,28]

Challenges Faced by Caregivers

During the lockdown, patients and caregivers could not arrange for blood donors and our blood bank was running short on

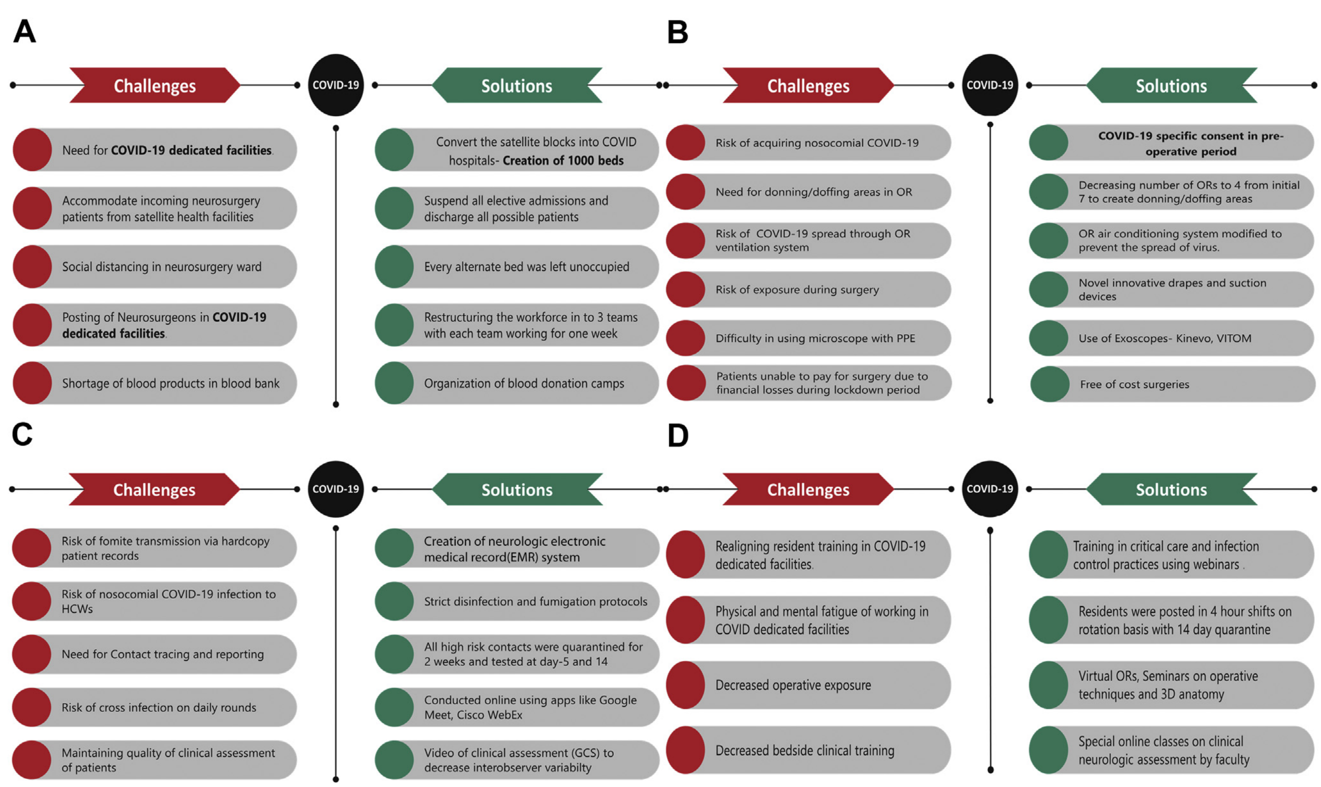


Figure 5. Summary of various challenges faced in neurosurgical practice during COVID-19 and solutions implemented in (**A**) infrastructure and resource allocation, (**B**) surgical practice, (**C**) infection control practices, and (**D**) resident training. 3D, three-dimensional; GCS, Glasgow Coma Scale; HCW, health care worker; OR, operating room; PPE, personal protective equipment.

supplies. A blood donation campaign organized by the resident doctors' association helped us in saving many lives. Entry of caregivers had to be restricted in wards because of the risk of cross-infection. Regular counseling of relatives by health care workers and ICU residents (twice daily) helped allay their anxiety and establish a proper communication mechanism. Audio or video calls were also used for this purpose for limiting the chance of cross-infection. Routine COVID-19 testing of the caregivers themselves would have been ideal but was not feasible because of logistic issues. However, the caregivers underwent temperature screening at all entrances to the neurosurgical block, were educated on safe practices, and were given surgical masks. Multiple blood donation campaigns were organized in which general public and personnel from police and paramilitary forces voluntarily donated blood. This strategy helped us tremendously in managing the scarcity of blood products.

COVID-19 Infection Among Doctors

Three of our residents developed COVID-19 symptoms. One of the residents was posted in a COVID-19 ward, whereas the others acquired infection from their family members who were also doctors and working in COVID-19-designated hospitals. We observed that use of proper PPE, stringent contact tracing, and timely diagnosis kept the incidence lower than in hospitals in developed countries.[29] Regular counseling and training of staff helped not only in allaying fears but also emphasized the importance of following good practices. Various measures implemented to control infection among patients and health care workers are summarized in Figure 5C.

Disruption of Training Program

The resident training program has been severely affected because of COVID-19.[30] |Of our residents, 25% have been posted in COVID-19-designated wards, where their domain knowledge is not required. Moreover, the decreased number of surgeries has limited their hands-on surgical exposure and learning. To improve their teaching, online classes/webinars were organized along with video presentations by our faculty and international faculty to teach surgical skills in line with other neurosurgical training institutes.[31,32] We further plan to organize simulation-based training in OR to improve hand–eye coordination using endoscope and microscope modules. We are also buying an advanced simulator to improve training. These solutions are elucidated in Figure 5D. We can plan hybrid workshops for residents to provide them with hands-on training on various models to provide better training than via online webinars.

Limitations

There was a predominance of elective procedures during 2019, whereas during lockdown in 2020, most patients were treated for emergency or semiemergency conditions, and, therefore, the 2 groups are not exactly comparable. Moreover, the sample size of patients during the study period is too small and heterogenous, precluding a detailed comparative analysis.

Difficulty encountered with the use of PPE could not be objectively assessed. The retrospective study design and single-center experience are yet other limitations of this study.

CONCLUSIONS

The challenges posed by the initial wave of COVID-19 in treating neurosurgical patients were tackled with solutions feasible for a resource-poor country. We have discussed these solutions that will not only help us in tackling a second wave of this pandemic but also help other institutions in India as well as other low-to-middle-income countries to be better prepared for similar circumstances.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Ravi Sharma: Writing - original draft, Methodology, Formal analysis. **Kanwaljeet Garg:** Methodology, Writing - original draft, Formal analysis. **Varidh Katiyar:** Formal analysis, Writing - original draft, Methodology. **Intekhab Alam:** Investigation, Methodology. **Vivek Tandon:** Formal analysis, Writing - original draft, Methodology. **Amol Raheja:** Formal analysis, Writing - original draft, Methodology. **Shashwat Mishra:** Formal analysis, Writing - original draft. **Pavana Veerabhadraiah:** Investigation, Methodology. **Ashish Suri:** Writing - review & editing, Methodology. **P. Sarat Chandra:** Writing - review & editing, Methodology. **Shashank Sharad Kale:** Writing - review & editing, Methodology.

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