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Neurosurgical Outcomes, Protocols, and Resource Management During Lockdown: Early Institutional Experience from One of the World's Largest COVID 19 Hotspots

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■ BACKGROUND: **As the COVID-19 pandemic surpasses 1 year, it is prudent to reflect on the challenges faced and the management strategies employed to tackle this overwhelming health care crisis. We undertook this study to validate our institutional protocols, which were formulated to cater to the change in volume and pattern of neurosurgical cases during the raging pandemic.**

■ METHODS: **All admitted patients scheduled to undergo major neurosurgical intervention during the lockdown period (15 March 2020 to 15 September 2020) were included in the study. The data involving surgery outcomes, disease pattern, anesthesia techniques, patient demographics, as well as COVID-19 status, were analyzed and compared with similar retrospective data of neurosurgical patients operated during the same time period in the previous year (15 March 2019 to 15 September 2019).**

■ RESULTS: **Barring significant increase in surgery for stroke ($P = 0.008$) and hydrocephalus ($P < 0.001$), the overall case load of neurosurgery during the study period in 2020 was 42.75% of that in 2019 ($P < 0.001$), attributable to a significant reduction in elective spine surgeries ($P < 0.001$). However, no significant difference was observed in the overall incidence of emergency and essential surgeries undertaken during the 2 time periods ($P = 0.482$). There was an increased incidence in the use of monitored anesthesia care techniques during emergency and essential neurosurgical procedures by the anesthesia team in 2020 ($P < 0.001$). COVID-19 patients had overall poor outcomes ($P = 0.003$), with significant increase in mortality among those subjected to general anesthesia vis-a-vis monitored anesthesia care ($P = 0.014$).**

■ CONCLUSIONS: **Despite a significant decrease in neurosurgical workload during the COVID-19 lockdown period in 2020, the volume of emergency and essential surgeries did not change much compared with the previous year. Surgery in COVID-19 patients is best avoided, unless critical, as the outcome in these patients is not favorable. The employment of monitored anesthesia care techniques like awake craniotomy and regional anesthesia facilitate a better outcome in the ongoing COVID-19 era.**

INTRODUCTION

The novel coronavirus disease (COVID-19) pandemic, which was first reported in Wuhan, China, continues to affect millions of people across 216 countries and territories, with the Mumbai metropolitan region emerging as one of the worst affected cities in the world and contributing to nearly half a million cases.[1,2] The primarily modes of transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) appears to be through droplet, contact, fomite, and airborne transmission.[3] Regions have been placed under various forms of lockdown, with restriction in movement of people, in an attempt to contain the spread of the disease. Neurosurgery centers form a unique subset that must cater to unavoidable

Key words
- COVID-19
- Monitored anesthesia care
- Neurosurgery protocols

Abbreviations and Acronyms
ELISA: Enzyme-linked immunosorbent assay
GA: General anesthesia
ICU: Intensive care unit
MAC: Monitored anesthesia care
PPE: Personal protection equipment
SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2

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neurologic emergencies like tumors, strokes, infections, and trauma. The pattern and volume of cases in neurosurgery centers across the world have changed significantly in the present scenario, leading to difficulties in resource planning and logistic management.[4-6] To prevent COVID-19 spread, various neurosurgical societies and institutions have published broad guidelines and recommendations, mostly based on third-party data.[7-11] These protocols remain to be validated, and surgical outcomes need to be analyzed. The aim of this study is to validate the COVID-19 protocols of our neurosurgery center and investigate the surgical outcomes. Another objective is to analyze the change in the disease pattern and neurosurgical volume, thereby establishing a benchmark for COVID-19 resource planning.

METHODS

This study was carried out at a tertiary care COVID-19 hospital, located in the Mumbai metropolitan region, one of world's largest COVID-19 hotspots. All patients who were admitted to the neurosurgery department of the hospital for a major procedure, in the lockdown period between 15 March 2020 and 15 September 2020, were included in the study. Outpatient procedures, diagnostic procedures, and minor surgeries were excluded from the study. As part of this study, surgery outcomes, disease pattern, anesthesia techniques, patient demographics, and COVID-19 status were analyzed. Outcomes were measured using the modified Rankin scale. They were compared with similar data, obtained retrospectively, from hospital records of neurosurgical patients operated between 15 March 2019 and 15 September 2019.

PROTOCOLS

All patients were triaged in priorities based on need for urgency of intervention (Table 1). All patients were also stratified based on COVID-19 status into 3 categories (i.e., COVID-19 positive, indeterminate and negative) and were managed in respective dedicated zones as per hospital protocol.

COVID-19 Testing Protocols

COVID-19 reverse transcription polymerase chain reaction test (COVID-19 RT-PCR) of nasopharyngeal and oropharyngeal swabs were performed in all patients requiring neurosurgery. In Priority I cases requiring immediate intervention, surgery was performed with full COVID-19 precautions and personal protection equipment (PPE), without waiting for results of COVID-19 reverse transcription polymerase chain reaction test. Following surgery, they were managed in a designated COVID-19 suspect intensive care unit until the availability of the COVID-19 report. In Priority I cases, those who could wait for a few hours before surgical intervention, faster diagnostic tests like Chip-based Real Time PCR Test (TrueNat SARS CoV-2), cartridge-based nucleic acid amplification test (GeneXpert Xpert Xpress SARS-CoV-2), or computed tomography of the chest with a COVID-19 Reporting and Data System score was done in addition to COVID-19 reverse transcription polymerase chain reaction test.[12] Priority II cases, who were diagnosed as having COVID-19, were closely monitored in a high-dependency unit and surgery was performed once they turned negative on COVID-19 RT-PCR. All operating room personnel were subject to mandatory screening daily, and the RT-PCR test was done per high-risk contact tracing protocols of our institution. Serosurveillance using enzyme-linked immunosorbent assay (ELISA IgG and IgM) was performed for all neurosurgery staff.

Anesthesia and Operating Room Protocols

A dedicated operating room with isolated donning and doffing areas, having separate entry and exit, was employed for confirmed or suspected COVID-19 cases. Minimal staffing was maintained during surgery. In the absence of a negative-pressure operating room in our institute, we designated a separate room with 2 split air conditioners of 2 tons of refrigeration capacity each, for conducting positive and suspected cases. All operating room personnel followed strict personal-protection measures including

Table 1. Stratification of Patients Into Priority Groups

Priority	Urgency	Representative Diseases	Recommendation
P1	Emergency surgery	Tumor causing significant mass effect Brain abscess Severe head injury Stroke Ruptured aneurysm Acute hydrocephalus Spine injury with neurologic deterioration Cauda equina syndrome	Immediate surgery/surgery within 24 hours
P2	Essential surgery	CNS tumor with decompensation Brain aneurysm Compressive myelopathy Extruded or herniated intervertebral disk disease with severe symptoms Chronic subdural hematoma	Surgery within 1 week
P3	Routine surgery	Degenerative spinal diseases Craniosynostosis	Postpone surgery

CNS, central nervous system.

PPE consisting of waterproof, hooded surgical gowns, N95 mask, shoe cover, and face shield with visor (Figure 1).

In a bid to minimize aerosol-generating procedures, general anesthesia (GA) and ventilation were avoided as much as possible during the perioperative period. If unavoidable, intubation was performed by the most experienced anesthesiologist in the operating room with the aid of a video laryngoscope. The plexiglass aerosol prevention box was used during all tracheal intubations, thus minimizing exposure of personnel to aerosolized virus. With the sole aim to minimize aerosol spread in the operating room, high-flow oxygen, nasal instrumentation, coughing, and bag-and-mask ventilation were avoided. Monitored anesthesia care (MAC), which included regional anesthesia, spinal anesthesia, and scalp block, was preferred to general anesthesia wherever possible.

All disposable items such as surgical drapes, breathing circuit, heat and moisture exchanger with viral filter, gas sampling line, reservoir bag, face mask, tracheal tubes, airways, and soda lime were discarded after every surgery per biomedical waste management protocols. All exposed surfaces such as anesthesia workstation, patient monitors, cabinets, and laptops were covered with disposable plastic sheets. The sheets were disposed at the end of surgery, and the surfaces were cleaned with disinfectant solution (1% sodium hypochlorite).

Neurosurgery Protocols

The strategy was to resect most of the tumors using awake craniotomy techniques and perform lumbar spine surgeries under spinal anesthesia. During cranial surgery, the patient was placed in a barrier tent, exposing only the part to be operated (see Figure 1). Monitoring of the surgical field was undertaken by incorporating a slave monitor. The neurosurgical team functioned as a compact and cohesive close-knit unit.

Craniotomy placement was planned to avoid paranasal sinuses. In cases of paranasal sinus breach, immediate containment was done using bonewax. An attempt was made to avoid surgical aerosol-generating procedures, such as bone drilling, Cavitron ultrasonic surgical aspiration, and monopolar cauterization. When their use was unavoidable, liberal irrigation and high-power suction were held close to the surgical field.

Statistical Analysis

The statistical analysis was done using a statistical package (IBM SPSS software V 25). The continuous variables (which were normally distributed) were summarized using mean and standard deviation and compared using Student's *t*-test. The categorical variables were summarized using contingency table and compared using the chi-square test. The 95% confidence interval was used to assess the precision of sample estimates, and alpha error was set to 0.05 for analyses.

RESULTS

A total of 67 patients were admitted for neurosurgical procedures during this period. Eleven cases were found to have COVID-19. Surgery was deferred in 5 cases who were COVID-19 positive and hence excluded from the study.

Brain tumor was the commonest diagnosis (25.80%), followed in incidence by spinal diseases (20.97%). Stroke constituted 12.90% of total cases (Table 2).

Of the 62 patients who were operated, 4 were diagnosed to have COVID-19 before surgery. In 13 instances, the COVID-19 testing was not done before surgery due to emergent nature of cases. These cases were empirically labeled as COVID-19 indeterminate, and surgery was performed with adequate COVID precautions and PPE. Of these 13 patients who were taken up for emergency

Figure 1. Neurosurgery operating room.

Table 2. Disease Pattern and Priority of Cases During Lockdown 2020 Versus 2019

	2020				2019				
Diagnosis	P1	P2	Total	Incidence %	P1	P2	P3	Total	*P* Value
Brain tumor	0	16	16	25.80	1	24	0	25	0.155
Stroke	8	0	8	12.90	6	0	0	6	0.021
Trauma	6	0	6	9.68	11	1	0	12	0.741
Vascular	3	3	6	9.68	9	7	13	29	0.070
Hydrocephalus	6	0	6	9.68	1	0	0	1	<0.001
Spine	3	10	13	20.97	2	12	56	70	<0.001
Miscellaneous	2	5	7	11.29	0	1	1	2	<0.001
Total	28	34	62	100%	30	45	70	145	<0.001

surgery, an immediate postoperative RT PCR turned out to be positive in 2 cases.

The overall caseload of surgeries in the study period in 2020 was only 42.75% of that in 2019, and it reflected a statistically decrease in the overall workload ($P < 0.001$) (Table 2). There was a significant increase in surgery for stroke ($P = 0.008$) and hydrocephalus ($P < 0.001$) in 2020 when compared with 2019. Most of the decrease in workload in 2020 could be attributed to a significant reduction in elective spine surgeries ($P < 0.001$). However, there was no significant difference in emergency and essential (P1 and P2) caseloads between 2019 and 2020 ($P = 0.482$) (Table 3). The patients of 2019 and 2020 groups were comparable with respect to age ($P = 0.291$) and sex ($P = 0.079$).

There was a statistically significant increase in MAC techniques among emergency and essential surgeries in the study period 2020 when compared with 2019 ($P < 0.001$). There was no significant difference in overall outcomes in cases during the COVID-19 and non-COVID period ($P = 0.237$). Though there were 3 deaths among the GA patients, there was no significant difference in outcomes in patients subjected to general anesthesia and MAC in 2020 ($P = 0.250$) (Table 4). However, patients who had COVID-19 disease had poorer outcomes when compared with those who were COVID free ($P = 0.003$). Further, there was a significant increase in mortality among COVID-19 patients subjected to GA when compared with MAC ($P = 0.014$).

None of the neurosurgery operating room personnel showed symptoms of COVID-19, and they tested negative on serologic survey using ELISA IgG and IgM tests and COVID-19 RT-PCR.

DISCUSSION

Coronavirus disease (COVID-19), caused by SARS-COV2, is primarily a respiratory disease that affects a myriad of organs and body systems including the nervous system.[13,14] COVID-19 disease has rapidly affected more than 49 million persons globally and has led to approximately 1.2 million deaths to date.[2] It has already crippled economies worldwide, and control of this pandemic still remains elusive. It has changed the pattern of patients reporting for various diseases and has led to reallocation of health care funds. Though there is an apparently growing plethora of literature on COVID-19, there is still a paucity of reliable scientific data based on first-hand experiences.[15-18]

Our hospital is located in the Mumbai metropolitan region, which has emerged as one of the largest conglomerations of COVID-19 cases in the world. All private and most of the government hospitals in Mumbai were converted to designated COVID hospitals with 80% of their beds allocated for care of SARS-CoV-2–positive patients. Our is a tertiary care referral hospital with 825 beds with 70 beds allotted for neurosurgery, of which neurosurgery intensive care unit (ICU) has 10 beds. During the comparison period (i.e., 15 March 2019 to 15 September 2019), the average bed occupancy rate was 78.3%. During the study period 15 March 2020 to 15 September 2020, the hospital added another 100 crisis expansion beds, of which 40 were COVID ICU beds. Being a designated COVID-19 hospital, 400 beds were earmarked for COVID-19 patients. The rest of the beds were reserved for emergency and acute cases, which included patients with post COVID-19 complications. The neurosurgery center was allotted 20 beds including 4 ICU beds. The hospital was overwhelmed with both COVID-19 and non-COVID patients, and the average bed occupancy rate was 95.8% during this period.

Being a dedicated service hospital, our clientele consists of serving armed forces personnel and their dependents, as well as veterans. However, per the government directive, the hospital services were extended to the entire community during the ongoing pandemic. Stringent protocols were ensured in the prioritization, segregation, and management of patients. These protocols were initially derived from guidelines of reputed organizations and societies, which we adapted to suit our requirements and subsequently modified based on our experience.[9,10,15,17,19-22]

The neurosurgical operation suite is a potential high-risk environment for the transmission of SARS-CoV-2 virus due to the requirement of undertaking aerosol-generating procedures like endotracheal intubation, mechanical ventilation, high-speed drilling, ultrasonic aspiration, and cauterization. Furthermore, the risk is enhanced by the proximity of oral and nasal orifices to the operative field and long duration of surgery in a contained

Table 3. Comparison of Demographics, Priority, Anesthesia, Ventilation, and Outcome Parameters Between Lockdown 2020 and 2019

Parameters	2020 (n = 62)	2019 (n = 145)	*P* Value
Priority			
P1 cases	28	29	<0.001
P2 cases	34	45	
P3 cases	0	71	
P1+ P2 cases	62	74	0.482
Demographics			
Age			0.291
Sex M:F	3.69:1 (48:13)	2.02:1 (97:48)	0.079
Anesthesia			
MAC	29	53	0.168
GA	33	92	
Anesthesia P1 + P2 cases			
MAC	29	9	<0.001
GA	33	65	
Postoperative ventilation			
Overall	10	22	0.862
P1 + P2	10	22	0.063
Overall outcome			
Improved	57	137	0.553
Worsened	2	5	
Death	3	3	
Outcome P1 + P2 cases			
Improved	57	68	0.676
Worsened	2	4	
Death	3	2	

MAC, monitored anesthesia care; GA, general anesthesia.

Table 4. Outcomes in Patients in Lockdown 2020

	Improved	Worsened	Death	Total	*P* Value
COVID status					
Negative	53	2	1	56	0.003
Positive	4	0	2	6	
Anesthesia					
GA	29	1	3	33	
MAC	28	1	0	29	0.250
Anesthesia in COVID patients					
GA	0	0	2	2	
MAC	4	0	0	4	0.014

GA, general anesthesia; MAC, monitored anesthesia care.

environment. Certain neurosurgical approaches like the transnasal transsphenoidal route for pituitary tumors, retromastoid surgery for cerebellopontine tumors, and supraorbital corridors for skull base pathologies are inherently more hazardous as they involve breech of paranasal sinuses.[23-26] The risk is enhanced by the requirement to discard some components of PPE like face shields while using an operating microscope and fiberoptic bronchoscope. In our study, none of the neurosurgery operating room personnel contracted COVID-19, as confirmed by RT PCR and serosurveillance with ELISA IgG and IgM, thereby validating the efficacy of our protocols. However, 2 personnel employed in the neurosurgical ward (a paramedical staff and a sanitation worker) tested positive for SARS-CoV-2.

There seems to be an absence of consensus regarding the safer type of anesthesia for COVID-19 patients. Some guidelines recommend regional and MAC, whereas others advocate general anesthesia.[21,22] Proponents of general anesthesia argue that intraoperative coughing during regional anesthesia may lead to aerosol generation and brain bulge.[22] However, we found that MAC techniques like awake craniotomy, regional anesthesia, and field blocks were safe, to both patients and the neurosurgical team in the current scenario. Because of the possibility of respiratory trauma caused by increased lung pressures during ventilation, a voluntary effort was made to perform the cases without a ventilator.[27] Almost half (46.77%; $n = 29$ of 62) of surgeries in priority 1 and 2 categories were performed using MAC in this lockdown period when compared with 12.16% ($n = 9$ out of 74) in the similar time in the previous year ($P = 0.001$). In our study, the outcomes of COVID-19 patients undergoing neurosurgery under MAC were significantly superior to those subjected to GA ($P = 0.014$). A weakness in our study is the small number of COVID-19 patients.

More evidence is emerging with each passing day regarding the optimal timing of surgery following SARS-CoV-2 infection. The recently published GlobalSurg-COVIDSurg Week multicenter prospective cohort study enrolled 140,727 patients undergoing surgery from 1674 hospitals in 116 countries. The researchers observed that risks of postoperative morbidity and mortality are greatest if patients are operated within 6 weeks of diagnosis of SARS-CoV-2 infection. The authors inferred that surgery should be delayed for at least 7 weeks following SARS-CoV-2 infection. COVID-19 patients who remain symptomatic for ≥7 weeks after infection may benefit from further delay.[28]

There was a statistical increase in the number of surgeries for stroke in this study period when compared with 2019 ($P = 0.021$). A myriad of nonspecific neurologic symptoms has been reported in COVID-19 patients in recently published literature. The various proposed mechanism of spread of SARS-CoV-2 virus to the brain included involvement of the olfactory bulb through the cribriform plate, leading to further dissemination, and blood-borne spread of virus leading to involvement of glial cells, neurons, and cerebral capillary endothelium through the ACE2 receptor pathway, indicating probable neurotropism.[14,29] Indirect mechanisms of brain injury include secondary damage due to hypoxia, coagulopathy, and immune-meditated neurologic injury.[14,29] Frequent neurologic symptoms include anosmia, altered sensorium, headache, and giddiness.[14,30] Some authors have reported an increased incidence of intracerebral hemorrhage, ischemic stroke, and cerebral venous thrombosis in patients suffering from COVID-19.[14,29,31] Rare cases of acute necrotizing encephalopathy, meningitis, and encephalitis have also been documents in these patients.[14,29,31]

In a study by Doglietto et al,[32] postoperative mortality, pulmonary complications, and thrombotic events were significantly higher in those with COVID-19 compared with control patients. In our protocol, as antibody testing for SARS-CoV-2 virus was not included, we were not aware if the patient had suffered from COVID-19 in the recent past. Though RT PCR remains the gold standard for diagnosis, it has a substantial false-negative rate, especially in the early phase of the disease.[33] Hence the exact incidence of patients who had suffered from COVID-19 in the past or those in the early stage of the disease remains speculative in our study. In our study there was no significant difference in surgical outcomes when compared with a matched control of patients in a similar time frame in the previous year. However, there was a statistically significant incidence of morbidity and mortality in the subgroup patients who were positive for COVID-19 ($P = 0.003$).

Many neurosurgery centers have reported a significant decrease in the number of cases undergoing surgery.[4-6,34-36] Appropriate resource allocation remains a challenge due to nonavailability of data regarding the volume and patterns of disease among neurosurgery patients on one hand and shortage of funds, as these have been diverted to manage this pandemic, on the other.[20,37,38] In our center, there was an ≈57% decrease in the total number of cases during this lockdown when compared with a similar timeframe in the previous year. However, there was no statistical decrease in the number of priority 1 and 2 cases. Cranial cases, especially brain tumors and strokes, accounted for majority of cases (79.03%). Much of the reduction in workload was due to a lesser number of elective spine surgeries. We attempt to set a guideline to aid centers in planning neurosurgical resource management, equipment, and logistic requirements. Neurosurgery centers must accordingly orient their resources and funds toward these essential procedures, as the load of these surgeries have not decreased significantly.

CONCLUSION

There was a significant decrease in neurosurgical workload in the COVID-19 lockdown period in 2020; however, the volume of emergency and essential surgeries remained the same as compared with the previous year. Hence resources must be appropriated accordingly to cater to these emergencies. Surgery in COVID-19 patients should be postponed, unless critical, as the outcomes in these patients are worse. Monitored anesthesia care techniques like awake craniotomy and regional and spinal anesthesia should be employed, wherever possible, to attain a better outcome in the COVID-19 era.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Manoharan Dwark Sudhan: Methodology, Formal analysis, Investigation, Writing – original draft. **Rupesh Kumar Singh:** Validation, Data curation. **Rahul Yadav:** Visualization, Writing – review & editing. **Rajeev Sivasankar:** Investigation, Data curation. **Sheila Samanta Mathai:** Supervision. **Ramakrishnan Shankaran:** Conceptualization. **Sachin Narayan Kulkarni:** Project administration. **Cherukuri Prakash Shanthanu:** Resources. **Lingappa Moolya Sandhya:** Software. **Azimuddin Shaikh:** Resources.

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