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Management of Neurosurgical Cases in a Tertiary Care Referral Hospital During the COVID-19 Pandemic: Lessons from a Middle-Income Country

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■ BACKGROUND: **The novel coronavirus disease 2019 (COVID-19) pandemic has been at its peak for the past 8 months and has affected more than 215 countries around the world. India is now the second most-affected nation with more than 48,000,000 cases and 79,000 deaths. Despite this, and the fact that it is a lower-middle-income nation, the number of deaths is almost one third that of the United States and one half that of Brazil. However, there has been no experience published from non—COVID-19—designated hospitals, where the aim is to manage noninfected cases with neurosurgical ailments while keeping the number of infected cases to a minimum.**

■ METHODS: **We analyzed the number of neurosurgical cases (nontrauma) done in the past 5 months (March—July 2020) in our institute, which is the largest neurosurgical center by volume in southern India, and compared the same to the concurrent 5 months in 2019 and 5 months preceding the pandemic. We also reviewed the total number of cases infected with COVID-19 managed during this time.**

■ RESULTS: **We operated a total of 630 cases (nontrauma) in these 5 months and had 9 COVID-19 infected cases operated during this time. There was a 57% ($P = 0.002$) reduction in the number of cases operated as compared with the same 5 months in the preceding year. We employed a dual strategy of rapid antigen testing and surgery for cases needing emergency intervention and reverse transcriptase-polymerase chain reaction test for elective cases. The hospital was divided into 3 zones (red, orange, and green) depending on infectivity level with minimal interaction. Separate teams were designated for each zone, and thus we were able to effectively manage even infected cases despite the absence of pulmonology/medical specialists.**

■ CONCLUSIONS: **We present a patient management protocol for non—COVID-19—designated hospitals in high-volume centers with the constraints of a lower-middle-income nation and demonstrate its effectiveness. Strict zoning targeted testing and effective triage can help in management during the pandemic.**

INTRODUCTION

The novel coronavirus disease 2019 (COVID-19) is a rapidly evolving situation where the possibilities are endless and certainties are limited. As of January 30, 102 million cases with 2.2 million deaths, this virus has affected over 215 countries.[1] The only certainty is that these numbers will continue to rise and infect more individuals. India is a lower-middle-income country by current World Bank classification,[2] which means its gross national income per capita is between $1036 and $4045. This has an implication on the number of tests per capita with India doing only 32.13 tests per thousand people as compared with 253.47 tests per thousand in the United States.[3] Despite this, the total

Key words
- COVID-19
- Neurosurgery
- Pandemic
- Zones

Abbreviations and Acronyms
COVID-19: Novel coronavirus 2019
DBS: Deep brain stimulation
MRI: Magnetic resonance imaging
OPD: Outpatient Department
PPE: Personal protective equipment
RAT: Rapid antigen test
RT-PCR: Reverse transcriptase—polymerase chain reaction

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number of deaths in India is nearly one third of that in the United States (154,000 vs 447,000 deaths), which could be attributed to the strict lockdown undertaken by the Union Government in India.[1] While the lockdown has been effective in reducing the total number of cases, it has undeniably reduced the number of neurosurgical caseloads even in the busiest of centers. Our center is a tertiary care hospital in South India that had a footfall of 224,265 cases in 2017–2018 with around 8900 surgeries per year, of which more than 4000 cases were major elective procedures.[4] The management of neurosurgical cases during this raging pandemic with the dual goals of providing the best neurosurgical care with minimum risk of infections under resource constraints poses a considerable challenge.

Bengaluru is the third most populous city in India with more than 20 million residents, and it reported its first confirmed case on 9 March, 2020.[5,6] This was close to the first case reported in India on 30 January, 2020, and much later than the first case in Wuhan in late December 2019.[6] We were able to use this time to make substantial preparations to face the pandemic. Being a high-volume center, one of our main concerns was crowd management and maintaining adequate social distancing and segregation in the space constraints that we had. A series of departmental protocols were put in place and measures were taken, including the postponement of elective surgeries, altered conventional outpatient service into telemedicine outpatient service, strict control of elective-emergency admissions, prevention of intermixing of cases and health care staff, improvements in operation and treatment processes, allocation of designated areas for holding and operating COVID patients and strict ward management. The objective of this report is to outline these measures and the impact that COVID-19 has had on the neurosurgical management of cases at our institute.

METHODS

We collected data for all neurosurgical cases operated during the 5 months of the pandemic (1 March 2020 to 31 July 2020) excluding trauma and compared the same to the number of cases operated during the same 5 months in 2019 and 5 months in the winter of 2019. For segregation of cases, the hospital was divided into 3 zones—red, orange, and green—with restricted transfer between each zone. After initial symptom screening, the patients were kept in the orange zone. Rapid antigen test (RAT) was employed for cases that required immediate surgery on an emergency basis. Such cases were operated using full personal protective equipment. Reverse transcriptase–polymerase chain reaction (RT-PCR) was used as the definitive test before transferring a case to the green zone for elective surgery. The red zone was used for rapid antigen and RT-PCR positive cases who needed emergency surgery.

Statistical Analysis

For category wise comparision with the past 5 months and 1 year back, the Mann-Whitney U test was used to compare the number of cases. A nonparametric test was used as the number of observations was <30 in each category of surgeries, considering it as nonnormal distribution. For the comparision of total cases with the 2 time periods (pre covid vs. the initial covid period including the lockdown) standard t-tests which a type of parametric method; they can be used when the samples satisfy the conditions of normality, equal variance, and independence.

RESULTS

Compared with last year, there was a 57% ($P = 0.002$) reduction in the number of surgeries done during the 5 months of the pandemic (Table 1), with a total of 630 cases operated over this duration as compared with 1448 cases in 5 months in 2019. When compared with the preceding 5 months, there was a 56% ($P = 0.009$) reduction in the number of cases operated (see Table 1). A total of 9 cases of confirmed COVID-19 positive cases were operated on during this period with no transmission to health care workers involved during the surgery (Table 2). A 3-tier management of patient inflow considering the emergent nature of the condition and rapidity of testing is thus demonstrated to be an effective management model (Figure 1) for high-volume resource-constrained hospitals. The most significant reduction was seen among neoplasm cases ($P = 0.015$ and $P = 0.028$), emphasizing the fact that many patients with neoplasms (benign and malignant) were delayed due to the pandemic.

MANAGEMENT PROTOCOL

Routine Management Protocol

In the pre–COVID-19 periods, neurosurgery patients were admitted through outpatient clinics and from emergency departments. All patients underwent thorough clinical evaluation, neuroimaging, along with routine investigations, and were operated on in 1 of the 7 elective or 3 emergency rooms. In 2018–2019, we operated more than 5700 cases (with >3000 elective cases) with 9 operative rooms (7 elective and 2 emergencies). Since then we have opened 2 more rooms that were dedicated to operating COVID-19 positive cases with neurosurgical emergencies.

In the Initial Phase of the Pandemic. During the initial COVID-19 period (Figure 1) when the number of positive cases was still low and an initial lockdown was in place, the admission was restricted to either from the emergency ward or a specially created holding ward where patients were admitted for RT-PCR testing before surgery. The emergency area was remodeled, and a special isolation ward was created where suspect patients were admitted for testing. An additional special triage area along with a testing kiosk was also created, where all patients who came to the Casualty Department were screened before being assigned to either the general triage area or the isolation ward. The hospital was divided into 3 zones: red—for all COVID-19–positive patients, orange—for emergency patients and those who were RAT negative, and green—for all RT-PCR–negative patients.

The screening protocol included a detailed questionnaire (see Figure 1), and a score was assigned to each patient to determine which ones were admitted, as detailed earlier. Also, every patient attendant had to undergo thermal screening, take a screening questionnaire, and use protective measures including hand sanitization and face masks, which were provided free of cost to them by the hospital.

Table 1. Comparison Between Number of Cases Operated During Pandemic (1 March to 31 July, 2020) to a Similar Period in 2019 and Preceding 5 Months

	01-03-2019 to 31-07-2019	01-10-19 to 29-02-20	01-03-2020 to 31-07-2020
Neoplasms			
Glioma	228	233	124 (−46%, −47%)
Posterior fossa tumors (cerebellar + fourth ventricular)	94	72	43 (−54%, −41%)
Intraventricular lesions	40	42	22 (−45%, −48%)
Convexity meningioma	69	64	43 (−38%, −33%)
Skull base meningioma	65	55	32 (−51%, −42%)
Vestibular schwannomas	53	36	25 (−53%, −31%)
Pituitary	49	56	14 (−72%, −75%)
Others (trigeminal schwannoma, ganglioglioma, etc.)	53	69	20 (−63%, −72%)
Vascular			
Ruptured aneurysms	117	154	98 (−17%, −37%)
Others (AVM, moyamoya)	38	10	10 (−74%, −71%)
Pediatric			
Neural tube defects	33	18	2 (−94%, −89%)
Craniosynostosis	11	12	3 (−73%, −75%)
Endoscopic procedures for hydrocephalus	30	64	25 (−17%, −65%)
Craniopharyngioma	28	24	12 (−58%, −50%)
Atlantoaxial dislocation and Chiari malformations	65	37	12 (−82%, −68%)
Spine			
Trauma	50	55	25 (−50%, −55%)
Degenerative	108	114	35 (−68%, −69%)
Tumors	73	64	24 (−77%, −62%)
Infections (including tuberculosis)	20	8	7 (−65%, −12%)
Functional			
Epilepsy	24	19	4 (−84%, −79%)
Movement disorder	14	16	0 (−100%, −100%)
Biopsy	34	35	16 (−53%, −55%)
Cranioplasty	69	69	13 (−82%, −82%)
Others (arachanoid cyst, trigeminal neuralgia, peripheral nerve, etc.)	83	21	21 (−75%, −71%)
Gamma Knife cases	148	192	42 (−72%, −75%)
Total operated (excluding Gamma Knife cases)	1448	1421	630 (−57%, −56%)

The 2 percentages in the last column indicate percentage change in the number of cases compared with a similar period in 2019 and preceding 5 months, respectively.
AVM, arteriovenous malformation.

In the Later Phase When the Cases Increased Exponentially. As the RAT became widely available, the strategy outlined earlier changed. All symptomatic patients and patients for emergency surgery were screened with RAT. As the turnover time for RAT at our institute is <30 minutes, it served as a useful tool, especially for triaging. The main disadvantage, though, was the sensitivity rate, which was around 50%. Also, all patients with an expected stay of >24 hours in the hospital were screened with RAT.

Personal Protective Measures. In the emergency/casualty area, all patients were evaluated by neurosurgery residents and nursing teams using protective measures like N95 masks or P100

Table 2. Cases of COVID-19–Positive Patients Operated During 1 March–31 to July 2020 ($n = 9$)

Age	Sex	Diagnosis	Procedure	PCR	OT
29	F	Right chronic SDH	Burr hole and evacuation	Positive	COVID OT
22	M	Cortical venous thrombosis	Decompressive hemicraniectomy	Positive	Casualty
22	M	Cortical venous thrombosis	Decompressive hemicraniectomy	Positive	Casualty
36	F	TBM hydrocephalus	VP shunt	Positive	Casualty
57	M	Right MCA aneurysm	Right pterional craniotomy and clipping	Positive	COVID OT
59	F	Right temporal glioma	Right temporal craniotomy and decompression	Positive	COVID OT
40	M	Right MCA infarct	Decompressive hemicraniectomy	Positive	COVID OT
33	M	Pituitary Macroadenoma	Right pterional craniotomy and excision	Positive	Routine
55	F	Craniopharyngioma	Right pterional craniotomy and excision	Positive	Routine - acquired after surgery/died

PCR, polymerase chain reaction; OT, operating theater; SDH, subdural hemorrhage; TBM, tuberculous meningitis; VP, ventriculoperitoneal; MCA, middle cerebral artery.

respirators, face shields, hand gloves, and impervious gown. All health care workers in the emergency area were mandated to be in personal protective equipment (PPE) gear.

Patient Management Protocol

Depending on the emergent nature of the illness (i.e., aneurysm rupture or signs of herniation), the patients were subjected to either throat nasopharyngeal swab for rapid antigen or nasal and oral swab for RT-PCR for SARS COVID-19. Depending on the results, the patients were operated on in the dedicated rooms as follows. Additionally, all patients being operated on in the orange and red zones underwent chest computed tomography.

- Red zone OT (2 dedicated rooms): All RAT-positive and RT-PCR–positive cases
- Orange zone OT (3 dedicated rooms): All RAT-negative patients
- Green zone: RT-PCR–negative patients

All COVID-19 patients operated at our institute were managed in the designated red zone ward until he or she was fit for discharge.

Personnel Precautions

All cases in orange and red zones were operated with the operating team in full PPE and N95 or P-100 respirators. Additional transparent face shields were worn during craniotomy along with copious irrigation. The central air conditioning was switched off during the procedure.

Health Care Personnel Precautions. All health care personnel with inadvertent exposure were assessed for risk and quarantined for 5 days followed by an RT-PCR test. A separate team of consultants and residents was designated to the red zone and not allowed to intermingle with doctors working in other zones, and a standard protocol was followed while in that area (Figure 2). Doctors working in the orange and red zones were to follow a strict work cycle of 1 week of work followed by a 1-week cooling period to reduce the risk of transmission among the health care workers.

OUTPATIENT DEPARTMENT SERVICES

Cases seen in the OPD were evaluated by neurosurgery consultant and resident teams using protective measures like N95 respirators, face shields, and hand gloves while taking adequate precautions to prevent crowding. If considered for admission depending on the nature of disease and need for surgery (Figure 3), they were shifted to the holding ward and an RT-PCR test was performed on them. If negative, these cases were shifted to the green zone to be operated in the 4 dedicated green zone rooms. Cases here were operated using face shields during craniotomy and N95 masks with protective eyegear throughout. After surgery, all patients were shifted to the postoperative ward, having shared cubicles with a restricted number of visitors/caregivers. They were all strictly observed for the development of any symptoms related to COVID 19.

Any patient who was RT-PCR positive and did not require emergent surgery was deferred until he became RT-PCR negative. Such patients were discharged to the designated COVID-19 hospitals for appropriate care.

TELEMEDICINE AND TELEPHONIC OUTPATIENT DEPARTMENT CONSULTATIONS

During the initial stringent lockdown, the OPD was closed. To minimize inconvenience to patients, telephone calls were made to patients for follow-up. Also, a dedicated number was set up to which the patients could call and set an appointment for telephonic consultation. During the telephonic consultation, relevant clinical details were sorted and if it was felt that the patients required a further evaluation, either a video telemedicine appointment was done or the patients were asked to come to the OPD at our institute or the nearest neurosurgical center.

The doctors enquired about the patient's identity through the government identity card. The doctors then introduced themselves, with their qualification, registration number, and specialization. The duration of the telemedicine consultation was fixed.

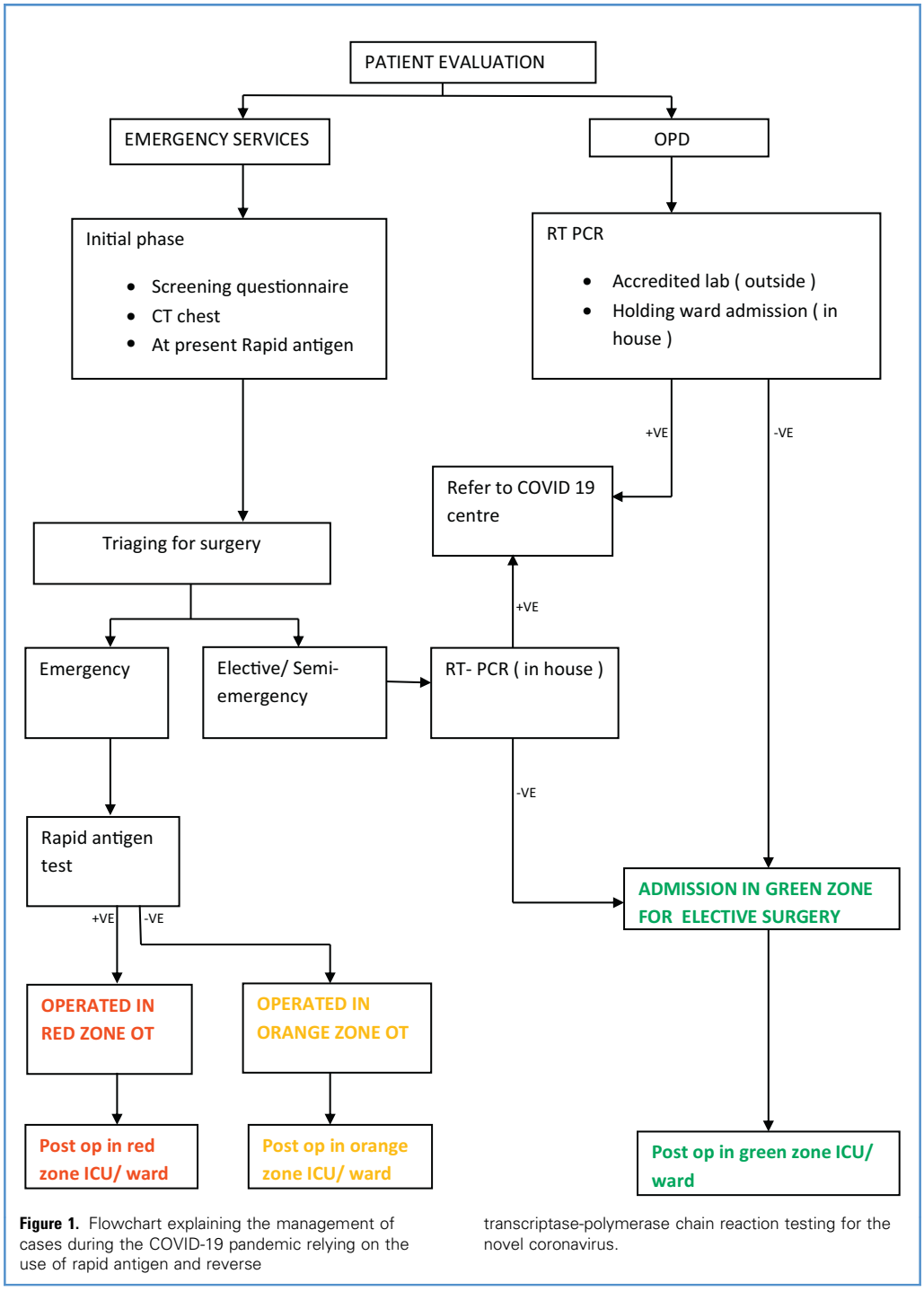

Figure 1. Flowchart explaining the management of cases during the COVID-19 pandemic relying on the use of rapid antigen and reverse transcriptase-polymerase chain reaction testing for the novel coronavirus.

The patient history and questions were kept precise and prepared before the telemedicine consultation. A properly filled proforma for the first or follow-up consultation helped in the documentation and to conduct the telemedicine session effectively. The previous treatment details/admission discharge slips were collected before the consultation. The presence of the patient was essential during the telemedicine consultation. The patient had the right to choose in-person consultation at any stage. Doctors also had the professional discretion to choose the mode of consultation (in-person/text/audio/video). Doctors needed to arrive at diagnosis/

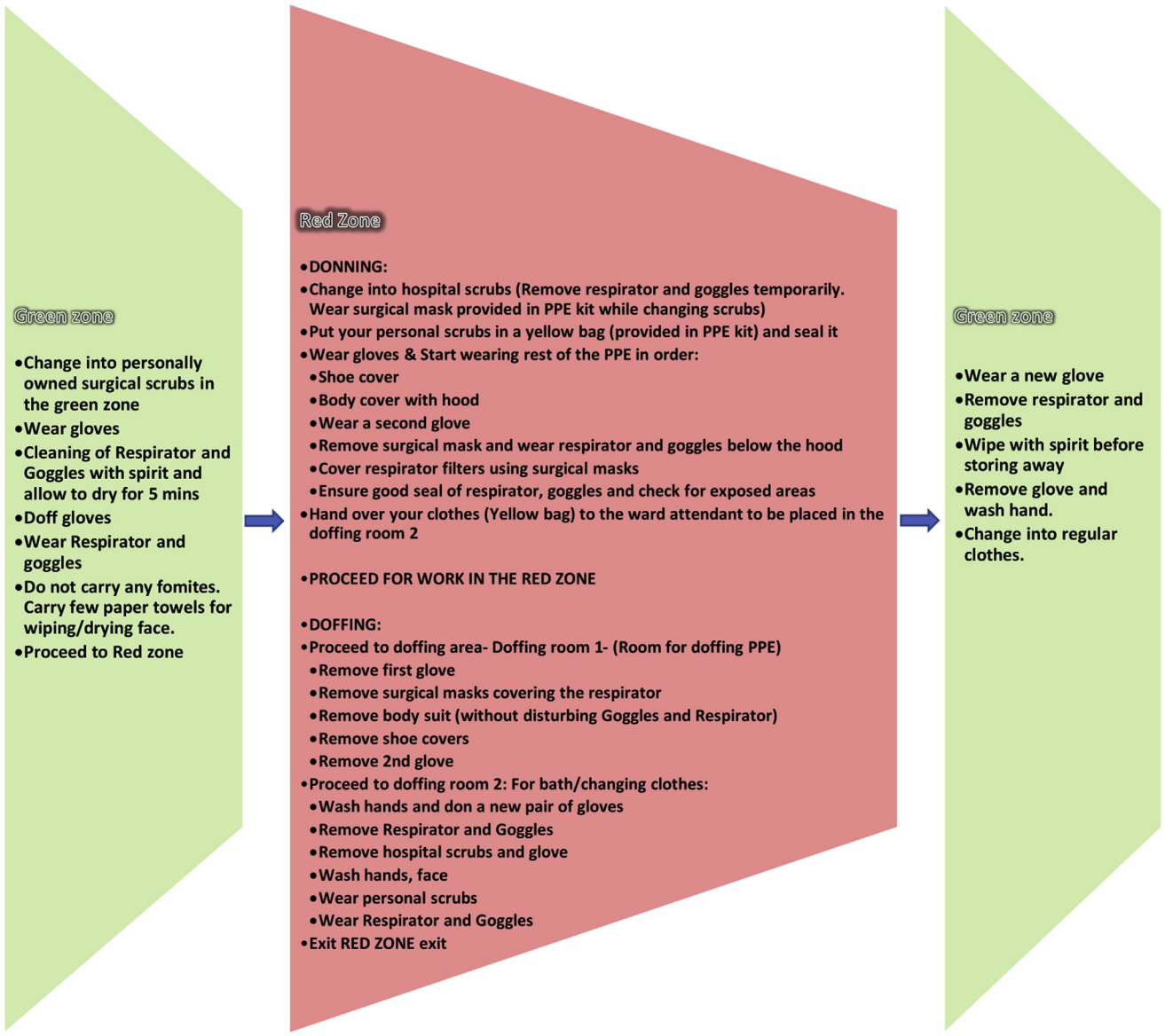

Figure 2. Stepwise personal protection during red zone duties.

provisional diagnosis before prescribing medication. They also avoided prescribing Schedule-X and drugs listed under the Narcotic Drugs and Psychotropic Substance Act, 1985.[7]

CASE SELECTION AND MANAGEMENT

We adhered to the selection of cases depending on the severity of the condition and urgency of care needed (see **Table 3**). All procedures that could be deferred (e.g., epilepsy, deep brain stimulation [DBS]) were delayed. Preference was given to patients with significant raised intracranial pressure, progressive neurologic deficits, aneurysms, etc. In cases such as low-grade glioma, where a period of interval monitoring with magnetic resonance imaging (MRI) is a reasonable management option, was also offered to these patients. In the event of a 3- to 6-month delay, we considered adding a 3-month interval scan to ensure no tumor progression.[8,9] Patients with certain diseases that are known to follow a benign course with a good level of evidence like cervical spondylotic myelopathy were advised to undergo surgery later, and clear instructions were provided to come to the hospital in case of neurologic deterioration. A separate consent was obtained from all admitted

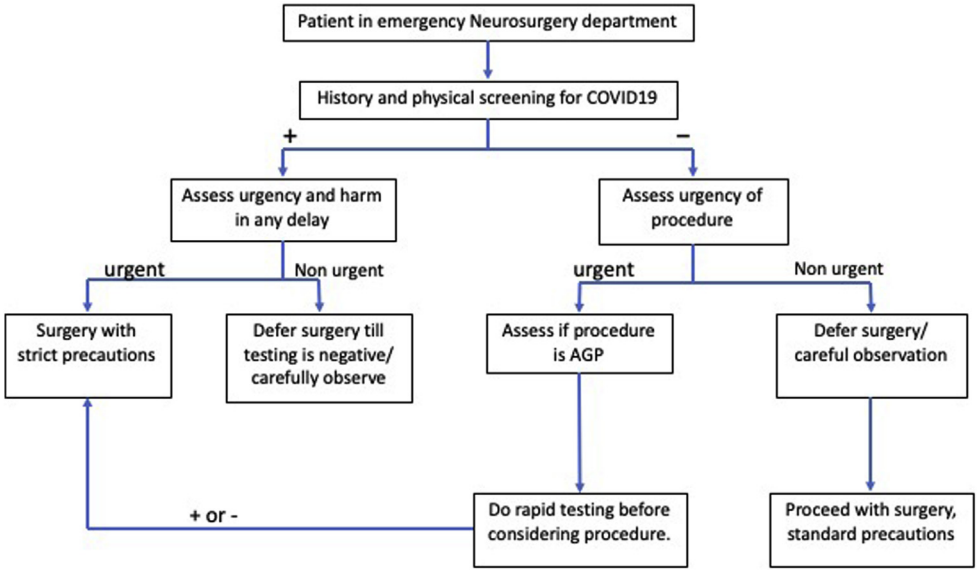

Figure 3. Management of cases presenting as an emergency during COVID-19 pandemic in our department.

patients elaborating about the ongoing pandemic and associated risks of transmission, in addition to routine admission and surgical consent.

Some ideas were used to help mitigate revisits to the OPD like using absorbable subcutaneous sutures for skin closure, requiring no extra visits for suture removal. Tracheostomy was done for cases presenting below Glasgow Coma Scale 8 during surgery or where a requirement for prolonged ventilation was suspected. Cerebrospinal fluid diversion was performed in cases of posterior fossa surgeries with a high risk of persistent hydrocephalus so that chances of cerebrospinal leak or hydrocephalus could be curtailed. Local services were encouraged to reduce travel and OPD numbers, especially for wound complications or immediate postoperative seizures. For complicated surgeries, 2 neurosurgeons worked synergistically to reduce the intraoperative time.[10] Double surgical gloves and minimal drilling/nibbling was done to avoid infection due to accidental glove ruptures. High-speed drilling was avoided, and electric drills were preferred to pneumatic drills. The use of CUSA was also minimized for the same reasons. The operating field was properly flooded with the irrigation fluid to minimize aerosol generation. For the initial few months, no transnasal procedures were performed and the tumors were operated on transcranially after explaining the concerns and consent obtained from the patient.

CASE LOAD COMPARISON AND COVID-19–Positive CASE MANAGEMENT

Comparing the number of cases to a similar period during the previous year, the maximum reduction was seen in functional neurosurgical cases like epilepsy surgery and movement disorders as these cases are being managed with medications as of now. Despite this, 3 cases of battery replacement were done for 2 patients with subthalamic nucleus–DBS for Parkinson disease (PD) and 1 with globus pallidus interna–DBS for generalized dystonia presenting with acute worsening of symptoms due to battery exhaustion.[11] Apart from these, there was a tremendous reduction in cases presenting with neural tube defects (94%) and craniosynostosis (73%). We have previously shown the prevalence of these defects is less in the southern part of our country when compared with other areas, and perhaps due to the restriction of travel, these cases were being managed locally.[12] Cranioplasty and pain-relieving procedures like trigeminal neuralgia were reduced by almost 80% as they were either deferred or managed medically. In addition, pituitary surgeries were also reduced by 72%, perhaps due to the unprecedented fear among cases and increased risk of infection associated with them.[13] There was little reduction in aneurysm surgery (17%) when compared with the summer months. However, the reduction seemed more (37%) when compared with winter months, during which the prevalence of aneurysmal subarachnoid hemorrhages is higher.[14] We also completely stopped cases done with intraoperative MRI guidance as it would entail increased exposure of the patient to the MRI suite. Our MRI suite is a hybrid and thus has a high footfall of cases undergoing routine MRI. Apart from these, there was no considerable difference in the number and composition of cases in summer and winters. We attributed the sudden decrease in number of cases to the pandemic.

A total of 9 COVID-19–positive cases were managed during this time, 7 of which were life-threatening emergencies, and 2 cases (pituitary and craniopharyngioma) presented with rapidly deteriorating vision. Eight of nine of these cases were discharged at modified Rankin Scale <2, signifying that proper case selection

Table 3. Adaptive Neurosurgery Acuity Scale Used for Case Selection During COVID-19 Pandemic, Especially for High-Volume, Middle-Income Countries

Category	Examples (Not Limited to)	Recommendation for Surgery
Emergent cases (high acuity)	■ Trauma ■ Stroke (SAH, ICH, IVH) ■ Large SOLs with significant MLS, with deterioration of consciousness ■ Spinal cord lesions with severe cord compression ■ Pituitary apoplexy with visual deterioration or altered sensorium ■ Acute hydrocephalous ■ Chronic SDH with significant MLS (>5 mm) ■ Cauda equina	■ Operate urgently ■ Wear full PPE if symptomatic or any significant history (international visit/contact with infected/HCW working in COVID-care units)
Urgent cases (high acuity)	■ Large SOLs without deterioration of consciousness ■ Malignant brain and spine tumors ■ Posterior fossa lesions ■ Spinal cord lesions without cord compression ■ Lesions lying near eloquent areas ■ Pituitary lesions with constant threat to vision ■ Chronic SDH without significant MLS (<5 mm) ■ Progressive cervical myelopathy ■ Brachial plexus injury	■ Patients must be screened for COVID-19 before surgery
Nonurgent cases (intermediate acuity)	■ Symptomatic benign intracranial lesions without local or generalized mass effect ■ Low-grade glioma ■ DBS for progressive parkinsonism ■ Refractory epilepsy ■ Spontaneous disk prolapse without significant neuronal compression ■ Small pituitary lesions with no mass effect ■ Unruptured aneurysm ■ Arteriovenous malformation ■ Craniosynostosis	Should be postponed if possible
Nonurgent cases (low acuity)	■ Peripheral nerve surgery (e.g., carpal tunnel release) ■ Benign intracranial (asymptomatic or mildly symptomatic) ■ Microvascular decompression of cranial nerves ■ DBS ■ Degenerative spinal pathology (lumbar stenosis, spinal deformity) ■ Gamma Knife radiosurgery	Postpone the surgery

SAH, subarachnoid hemorrhage; ICH, intracerebral hematoma; IVH, intraventricular hematoma; SOL, space-occupying lesion; MLS, midline shift; PPE, personal protective equipment; HCW, health care worker; SDH, subdural hematoma; DBS, deep brain stimulation.

can lead to gratifying results, even in these cases. One case of craniopharyngioma acquired COVID-19 infection from another case (unknown source) after surgery. He later succumbed to the virus due to severe acute respiratory distress syndrome.

GAMMA KNIFE RADIOSURGERY DURING COVID

We were able to successfully run the Gamma Knife facility during this time without interruption and do 42 cases in 5 months (70% reduction) and no infections (see Table 1). This meant that every

case was pretested with RT-PCR within the prior 2 days of receiving treatment along with 1 relative. Any patient suffering from cough, fever, loss of smell, or history/contact to the COVID affected area was either tested twice 1 week apart or rescheduled, as most of these cases are not emergencies. Radiosurgery is a multidisciplinary team that involves a neurosurgeon, radiation oncologist, medical physicist, nursing staff, and radiotechnicians. To minimize the chances of unnecessary exposure, only 1 team leader fixed the frame for the patient. While minimally symptomatic patients such as those with a growing vestibular schwannoma or residual nonfunctional pituitary adenoma were given a lower priority, a single or oligometastatic lesion of the brain with favorable outcomes was prioritized urgently. As the intubation and elective ventilation were considered high-risk procedures concerning coronavirus, we refrained from pediatric patients and the ones in need of anesthesia during Gamma Knife radiosurgery. We considered the frame localizer and frame engaging unit over the Gamma Knife couch as infected material and sterilized it after every procedure. Air conditioning was avoided. The staff was encouraged to use the no-touch technique and frequently disinfect with alcohol. All surfaces were repeatedly cleaned with alcohol-based solutions including computer apparatus, keyboards, and mouse. A single operator was asked to handle data entry, image definition, target and organs at risk delineation, treatment planning, and approval. Steroids were used judiciously in posttreatment cases with no more than a 7-day course in lesions presenting with edema. Using these precautions, we were able to achieve a zero-infection rate while maintaining the standard of care without affecting our workload.

DISCUSSION

Our center is the biggest neurosurgical center in South India that caters only to neurologic diseases with only visiting specialists employed in the field of general and respiratory medicine and thus is not an ideal setup for the management of COVID-19 cases. Though we are not a COVID-19–designated center, all COVID-19 patients who were operated on here were managed in-house with consultations from the adjoining chest disease hospital. We have shown that with rigorous screening and case selection, the safety of inpatients and health workers can be ensured. Although there has been a significant drop in the number of cases operated, we have triaged cases according to their needs and operated whenever necessary. Also, procedures that can buy time like third ventriculostomies and biopsies for irresectable tumors did not change despite the fall in overall numbers (only 17%).[15] While negative pressure suction rooms are preferred for performing surgical procedures, this may not be possible in developing countries as these facilities may not be available in all surgical centers. So, rapid antigen screening and division of hospitals into zones as shown may be practical measures among inpatients. A single negative test for emergency procedures and RT-PCR negative tests for elective cases ensures the safety of surgeons, assistants, and technicians in the operating rooms (ORs). In the recovery wards, all nursing staff and attending doctors take protective measures including masks, face shields, and gloves. The use of a face shield has been made mandatory for airway suctioning in all areas,[16] and it has shown to be effective in addition to the use of masks.

Rapid antigen tests, although having a notoriously low sensitivity (50%),[17] can help in cases where the person is asymptomatic and needs rapid intervention. Also, computed tomography of the chest can help weed out cases that are doubtful in terms of COVID infection, which requires rapid intervention. In a resource-constrained environment like ours, as much as 20%–30% of all tests now being done are rapid antigen tests.[17] In addition to using standard precautions like minimal drilling and copious irrigation, certain low-cost but highly effective solutions were used like boxed intubation (**Figure 4**), which prevented aerosol spread, and minimum personnel in the room while intubating. Also, extubating on the table and doing 1 case per room prevents cross-infection and gives enough time for proper sterilization. High-risk anesthetic procedures included intubation, extubation, mask ventilation, open suctioning of respiratory secretions, awake intubation, high-flow nasal oxygen, and cardiopulmonary resuscitation. Low-risk procedures included EVD placement and lumbar drain placement. Only the necessary equipment was kept, and preferably disposable ones were used in confirmed cases. Clear delineation of roles, airway plan, and cross monitoring of all team members for potential contamination along with reducing the number of individuals in the room at a time would be beneficial.[18] Efforts must be made to ensure fit testing of the N95 mask for all at-risk staff as nonfit tested use of N95 mask contributed to transmission to health care worker. Alternate to an N95 mask, half/full-face respirators, or powered air-purifying respirators can be used if available. These have shown good efficacy and better protection.[19]

CONTROLLED MANAGEMENT OF CASES

Unfamiliar techniques are to be avoided. Endobronchial intubation should be checked with flexion of the neck if needed for surgery to avoid ventilator disconnections later. Conducting awake intubation and awake surgeries is discouraged as they tend to generate more aerosols. However, if inevitable, every precaution should be taken to minimize aerosol generation.[20] Lower cranial nerve monitoring electrode placement should be done after intubation with a vasopressor ready in case of hypotension. After extubation, it should be ensured that the patient wears a face mask immediately and there should be strict adherence to doffing protocols. All disposable sensors used for neuromonitoring must be discarded.[21,22]

There are reports from China, from before the introduction of containment measures that show the degree of contamination of hospitals, implying the potential of hospitals developing as "hotspots" for the spread of the virus. One report from Wuhan, China shows that 31.9% of the surface swabs collected from the intensive care unit and 28.1% from the obstetric ward were contaminated by the virus.[23] Two-hundred and fifteen mothers who were admitted to the New York-Presbyterian Allen Hospital and Columbia University Irving Medical Center were screened with RT-PCR, and 15.4% of them were found to be positive for the virus.[24] Thus there is a potential for hospitals to become epicenters for the transmission of disease unless precautions are taken for the containment of its spread.[25]

The strategy of dividing the hospital into zones for the prevention of the spread of infection, judicious use of PPE, and

Figure 4. Box intubation used to prevent aerosol exposure during intubation.

efficient patient care for non-COVID diseases have its roots in Systems Engineering Initiative for Patient Safety, which is a human factor-based model used in health care to understand the impact of a working system and processes on outcomes.[26] Although the guidelines by the Indian ministry of health are not developed specifically for non-COVID hospitals, we have adopted most of the relevant guidelines and made necessary modifications, like the creation of designated infrastructure and staff for the management of patients with COVID infection who require urgent neurosurgical intervention.

PRACTICE GUIDELINES FROM INDIA

The senior author (DS) contributed to the consensus guidelines regarding the practice of neurosurgery and neurology from India.[15] These guidelines are applicable in the OR while taking neurosurgery rounds and preoperative and postoperative management. We tried to emulate the same at our hospital, and a summary follows:

1. Preprocedure briefing: Each member of the team should understand the sequence of anesthesia and surgery, as this will ensure seamless teamwork with all the necessary drugs and equipment in place before commencement of the operating procedure.
2. Negative pressure OR preferred; however, high frequency of air change (25/hour) is equally effective.
3. Separate OR with separate air duct flow for managing COVID-19 cases: Each OR should have its ventilation system with an integrated high-efficiency particulate air filter.
4. Creating a set of new workflows (e.g., coordination of staff, movement of surgical and anesthetic equipment, infection prevention practices).
5. A comprehensive program for the use of PPE must be enforced.
6. Discard the canister of soda lime to eliminate the negligible risk of circuit contamination after surgery.
7. Following the disposal of single-use equipment, all instruments should be sent for decontamination and sterile reprocessing.
8. All staff should then shower and change into a clean set of scrubs.
9. "High-touch" equipment (e.g., anesthesia stations, laptops, cabinets) should be covered with disposable plastic sheets.
10. Names of all participating staff members are recorded to facilitate contact tracing. Since more time is required for decontamination, the turn-around time for surgery is naturally increased.

There is a dual priority of personal protection while ensuring patients' safety, timely management, and capacity building. Along with the glaring problem of infection, there is another threat of neurosurgery emergency building up. This wave may overwhelm the already stretched systems to the hilt. We need to flatten this curve while avoiding contagion. These measures may guide neurosurgery practitioners to effectively manage patients ensuring the safety of caregivers and care seekers.[27,28]

NEUROSURGICAL TEACHING

Ours is a training institute where 10 resident neurosurgeons are enrolled every year with a total strength of around 40 residents at any given point in time. The decreased volume and limited spectrum of neurosurgery cases have affected neurosurgery training adversely. The reduction in clinical and surgical exposure is likely to hamper their operative and clinical skills. Our department has circumvented this by holding online teaching sessions along with interdepartmental online meetings with neuropathology for slide and case discussions in addition to regular seminars and journal clubs. Also, videos of previously operated cases may be revisited via video conferencing to overcome this draught in surgical exposure.

Limitations

Ours is a retrospective analysis in a tertiary care institute funded by the Union Government of India. Thus, while the caseload is huge, so are the resources when compared with the rest of the country. We understand that many of these measures require huge manpower, which may not be possible in every institution. Besides, the period of study is small with a noncontrolled design. Despite this, such studies from middle-income countries are few and thus every protocol is important such that it may be applicable in a setting elsewhere. As it is already known, different medical centers in different countries or even within the same country are heterogeneous regarding their resources, level of experience, and facilities. So, readers would be best advised to read critically the proposed management protocol and choose what is suitable for the working environment and surroundings.

CONCLUSION

The ongoing pandemic has exposed several loopholes in the worldwide health care system. A sizeable number of global fatalities have occurred, and the impact is being felt worldwide. We have successfully managed neurosurgical cases despite not being a COVID-19–designated hospital and without the presence of pulmonologists or even medical specialists. Effective steps were taken by us, such as zoning, triaging, and managing the workload with constraints to prevent neurologic deterioration of elective cases waiting for surgery and presenting acutely, have proven effective. We present this model for high-volume centers in middle-income nations where testing and nonavailability of critical care beds are a reality.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Harsh Deora: Conceptualization, Methodology, Software, Writing - review & editing. **Preetham Dange:** Data curation, Writing - original draft, Formal analysis, Software. **Kautilya Patel:** Data curation, Writing - original draft, Formal analysis, Software. **Abhinith Shashidhar:** Visualization, Investigation. **Gaurav Tyagi:** Visualization, Investigation. **Nupur Pruthi:** Writing - review & editing, Supervision, Validation. **Arimappamagan Arivazhagan:** Writing - review & editing, Supervision, Validation. **Dhaval Shukla:** Writing - review & editing, Supervision, Validation. **Srinivas Dwarakanath:** Conceptualization, Methodology, Software, Writing - review & editing, Supervision, Validation.

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