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Neurosurgical Procedures and Safety During the COVID-19 Pandemic: A Case-Control Multicenter Study

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■ OBJECTIVE: **Quantitative documentation of the effects of outbreaks, including the coronavirus disease 2019 (COVID-19) pandemic, is limited in neurosurgery. Our study aimed to evaluate the effects of the COVID-19 pandemic on neurosurgical practice and to determine whether surgical procedures are associated with increased morbidity and mortality.**

■ METHODS: **A multicenter case-control study was conducted, involving patients who underwent neurosurgical intervention in the Kingdom of Saudi Arabia during 2 periods: pre-COVID-19 and during the COVID-19 pandemic. The surgical intervention data evaluated included diagnostic category, case priority, complications, length of hospital stay, and 30-day mortality.**

■ RESULTS: **A total of 850 procedures were included, 36% during COVID-19. The median number of procedures per day was significantly lower during the COVID-19 period (5.5 cases) than during the pre-COVID-19 period (12 cases; $P < 0.0001$). Complications, length of hospital stay, and 30-day mortality did not differ during the pandemic. In a multivariate analysis comparing both periods, case priority levels 1 (immediate) (odds ratio [OR], 1.82; 95% confidence interval [CI], 1.24—2.67), 1 (1—24 h) (OR, 1.63; 95% CI, 1.10—2.41), and 4 (OR, 0.28; 95% CI, 0.19—0.42) showed significant differences.**

■ CONCLUSIONS: **During the early phase of the COVID-19 pandemic, the overall number of neurosurgical procedures declined, but the load of emergency procedures remained the same, thus highlighting the need to allocate sufficient resources for emergencies. More importantly, performing neurosurgical procedures during the pandemic in regions with limited effects of the outbreak on the health care system was safe. Our findings may aid in developing guidelines for acute and long-term care during pandemics in surgical subspecialties.**

Key words
- COVID-19
- Neurosurgery
- Pandemic
- Triage
- Surgical outcome

Abbreviations and Acronyms

CI: Confidence interval
COVID-19: Coronavirus disease 2019
OR: Odds ratio

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INTRODUCTION

Since the beginning of the twenty-first century, the world has experienced a series of major crises as a result of infectious disease outbreaks.[1] These outbreaks and their effects on global public health accelerated the revision of the International Health Regulations (2005), which took effect in 2007.[2] The definition of a pandemic was revised to an increased and sustained transmission of a disease in the general population, over a wide area crossing international boundaries.[3]

The World Health Organization declared the coronavirus disease 2019 (COVID-19) outbreak a pandemic on March 11, 2020.[4] As of May 20, the number of infections reported worldwide reached 4,789,205 cases, and the global reported death toll was 318,789 patients.[5] This viral illness was first discovered in Wuhan, Hubei Province, China, on December 31, 2019.[6,7] As COVID-19 spread beyond China, governments and health care systems responded by implementing containment measures with varying degrees of restriction.[8] The local consequences of a pandemic can be complex to manage, because of increasing demands for health care that can exceed the capacity of a health system.[9-11] Simultaneously, outbreaks are associated with increased hospitalization and mortality.[12,13] Observations from previous outbreaks have shown changes in the use of health care services during the outbreak.[14-18]

The literature describing the changes in surgical services during outbreaks, including COVID-19, is limited to subjective retrospective evaluations using questionnaires and surveys.[19-24] The reported observations from those studies have described increased surgical cancellation rates and a decline in the number of elective cases, on the basis of subjective survey responses from surgeons. In this unmatched case-control study, we objectively analyzed the effects of the COVID-19 pandemic on neurosurgical services. Moreover, we evaluated the distribution of cases, number of neurosurgical procedures, type of cases, and patient safety profiles.

METHODS

Study Design and Setting

We conducted a multicenter unmatched case-control study among participating surgeons to assess the effects of the COVID-19 pandemic on their surgical practices. We included centers from all geographic regions in the Kingdom of Saudi Arabia, including both private and public hospitals that provide full neurosurgical services. The public hospitals included ministry of health, academic, and military hospitals. This study was approved by the institutional review board at King Saud University Medical City, Riyadh, Saudi Arabia (number 20/0341/IRB). We followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting guidelines in reporting the results of this study.[25]

Data Source and Variables

Data were collected retrospectively from 29 neurosurgeons. All participating neurosurgeons were fully privileged consultants at their institutes, who had been practicing for >2 years. After the World Health Organization declared COVID-19 a pandemic, we collected patient demographics and surgical intervention information for 2 periods: pre-COVID-19 (from March 11, 2019 to April 30, 2019) and during the COVID-19 pandemic (from March 11, 2020 to April 30, 2020). We included both adult and pediatric neurosurgical procedures. The patient demographic information included age, sex, and institution type (public or private), and the surgical intervention information included diagnosis, category of surgical intervention, case priority, general and craniospinal complications, length of hospital stay, and 30-day mortality. We defined the case categories as trauma, oncology, spine, vascular, congenital, hydrocephalus, peripheral nerve, functional, and infection. We defined the priority of cases according to the Saudi Association of Neurological Surgery priority list (Table 1).[26] Four major priorities were defined. Priority 1 (immediate) is for patients requiring immediate intervention. Priority 1 (1–24 h) is for cases of urgent patients who should be treated within 24 hours of presentation. Priority 2 is for patients requiring intervention within 1 week, whereas priority 3 is for patients requiring intervention within 1–4 weeks. Priority 4 patients are those whose interventions can be delayed for >4 weeks. During the COVID-19 period, we collected data on the status of COVID-19 testing, timing of testing, and COVID-19–related complications.

Statistical Analysis

We divided the patients into 2 groups: pre-COVID-19 and during COVID-19. The demographic and surgical intervention characteristics between groups were compared with a 2-way t test if the data were normally distributed or a Mann-Whitney test if the data were nonnormally distributed, and Pearson χ^2 test was used for cross-tabulation data. Univariate and multivariate logistic regression were used to predict the differences in neurosurgical intervention variables between the pre-COVID-19 and during the COVID-19 groups. The covariates in the multivariate logistic regression models were age, sex, and institution type (public or private). We tested all models for goodness of fit by using deviance statistics and the Hosmer-Lemeshow test. A P value <0.05 was considered statistically significant. We used Stata 14 statistical software (StataCorp LLC, College Station, Texas, USA) for statistical analysis.

RESULTS

We analyzed 850 procedures: 545 (64%) in the pre-COVID-19 period and 305 (36%) in the COVID-19 period. Table 2 shows the demographic and surgical intervention information. The mean ages were 37 years (standard deviation, 22.5 years) and 34.9 years (standard deviation, 23 years) in the pre-COVID-19 and COVID-19 periods, respectively. Males were dominant in our sample, which included 490 males (57.7%) and 360 females (42.3%). During the COVID-19 period, 62 patients (20.3%) underwent COVID-19 testing via nasopharyngeal swabs. Only 1 patient had positive results and underwent 2 subsequent retests 3 days apart, which yielded negative results; the patient showed no signs of fever or upper respiratory tract infection.

The median number of neurosurgical procedures per day was significantly lower during the COVID-19 period (5.5 cases; interquartile range, 3–8) than during the pre-COVID-19 period (12 cases; interquartile range, 6–15; $P \leq 0.0001$). Public hospitals handled most of the cases in both periods: 398 (73%) in the pre-COVID-19 period versus 212 (69.5%) in the COVID-19 period ($P = 0.27$). During the pandemic, 70 procedures were performed in the first week, which decreased to 40, 40, and 43 per week in weeks 5, 6, and 7, respectively (**Figure 1**).

Regarding the distribution of case categories during each period, only the peripheral nerve subspecialty showed significantly fewer cases in the COVID-19 period (1.6%) than in the pre-COVID-19 period (5.3%) ($P \leq 0.01$). We found no statistically significant differences in other neurosurgical categories between groups. Regarding case priority, the percentage of priority 1 (immediate) cases was higher in the COVID-19 period (20.3%) than in the pre-COVID-19 period (12.3%; $P \leq 0.01$). Similarly, the percentage of priority 1 (1–24 h) cases was higher during the COVID-19 period (18.7%) than during the pre-COVID-19 period (12.5%; $P = 0.01$). However, the percentage of priority 4 cases was significantly lower during the COVID-19 period (13.4%) than during the pre-COVID-19 period (32.6%; $P \leq 0.0001$).

Complications were reported in 2 separate groups: general and craniospinal. General complications occurred at a rate of 5.7% pre-COVID-19 compared with 3.61% during COVID-19, whereas craniospinal complications occurred at a rate of 9.17% pre-COVID-19 compared with 9.18% during COVID-19. The 30-day mortality was 1.8% and 1.6% in the pre-COVID-19 and COVID-19 periods, respectively. The median length of stay was 7 days (range, 4–14 days) in the pre-COVID-19 period compared with 6 days (range, 3–14.5 days) in the COVID-19 period. No statistically significant differences were found in complications, length of stay, and 30-day mortality between the pre-COVID-19 and COVID-19 periods.

In **Table 3**, multivariate logistic regression was used to predict the differences in diagnosis category, case priority, and institution type between the pre-COVID-19 and COVID-19 pandemic groups. The covariates in the multivariate logistics regression models were age, sex, and institution type. Regarding diagnosis category, peripheral nerve (odds ratio [OR], 0.29; 95% confidence interval [CI], 0.11–0.78), and functional (OR, 0.35; 95% CI, 0.13–0.94) subspecialty interventions were significantly lower in the COVID-19 group. There were no significant differences in other subspecialty categories during COVID-19 versus pre-COVID-19. Priority levels 1 (immediate) (OR, 1.82; 95% CI, 1.24–2.67), 1 (1–24 h) (OR, 1.63; 95% CI, 1.10–2.41), and 4 (OR, 0.28; 95% CI, 0.19–0.42) showed significant changes.

In public hospitals, the rate of priority 1 (immediate) was lower pre-COVID-19 (14%) than during COVID-19 (24%) ($P = 0.001$). The rate of priority 1 (1–24 h) was lower pre-COVID-19 (14.5%) than during COVID-19 (22.6%) ($P = 0.01$). Priority 4 was higher pre-COVID-19 (26.6%) than during COVID-19 (4.7%) ($P \leq 0.001$). In private hospitals, priority 4 was higher pre-COVID-19 (49%) than during COVID-19 (33.3%) ($P = 0.02$) (**Figure 2**).

DISCUSSION

Our study showed a 44% decrease in the number of neurosurgical procedures performed during the COVID-19 pandemic. Analysis of current and previous outbreaks has indicated a change in the use of health care services in hospital admissions, outpatient services, and emergency visits.[14-18,27] In a recent survey investigating the effects of the COVID-19 pandemic on 661 neurosurgeons from 96 countries,[21] the overall cancellation rate for elective clinical visits and surgeries reached 57.5% and 51.9% in private and public practice, respectively. The investigators reported that 76% of the cancellations were related to government directions, 14% were related to physician preference, and 7% were related to patient preference. Although not evaluated in our report, the observed decrease in the number of cases may have been linked to the application of strict guidelines in hospitals and the reorganization of the surgical workforce to enhance front-line health care delivery during the pandemic.[27-29]

We observed a stabilization in the number of cases per week in the last 3 weeks of our study period (**Figure 1**). The exact cause of this stabilization late in the course of the pandemic in our report could not be linked to any of the evaluated variables. In a recent questionnaire evaluating changes in surgical volume early and late in the course of the COVID-19 pandemic, 82% of respondents reported stricter hospital policies regarding inpatient hospital services. Slight changes have also been reported in the personal assessment of the risk associated with delaying surgeries in specific neurologic disease scenarios over the course of the pandemic.[20]

Examining the distribution of the encountered cases according to diagnosis category is important during outbreaks to allow for appropriate allocation of resources. In our report, we objectively collected information on actual cases as well as clinical data to document procedures performed during the COVID-19 pandemic. Despite the significant decrease in the number of procedures observed in our report, the distribution of cases among neurosurgical subspecialties did not change significantly. The 2 major declines in the number of cases were observed for peripheral nerves and functional procedures. This result may be related to the elective nature of these 2 neurosurgical subspecialties, in which most cases are usually assigned priority 4. However, oncology, hydrocephalus, and trauma cases showed a slight percentage increase over the pre-COVID-19 period, but this change did not reach statistical significance. Most COVID-19–related guidelines prioritize oncologic cases, thus explaining the percentage increase in oncologic procedures observed in our study. This finding is in line with those from a recent international self-reporting survey showing overall agreement among participating neurosurgeons that clinically stable but evolving oncologic cases have a high risk of complications as a result of postponement because of the COVID-19 pandemic.[20]

In neurosurgery, several organizations have published guidelines aimed at prioritizing cases and implementing an algorithm for managing neurosurgery patients.[26,28-30] Rearranging the neurosurgical waiting list according to priority can play an important role in ensuring the timely delivery of services. Despite the decrease in the total number of procedures, we documented similar numbers of emergency cases (priority 1) during the pandemic period compared with the previous year. The OR was 1.82 for priority 1 (immediate) procedures when the COVID-19 and pre-COVID-19 periods were compared. However, a significant decrease was observed in both the total number and the OR for elective cases (priority 4). There was no significant change in the distribution of case diagnosis categories within priority 1 during the 2 periods. Within the same priority (priority 1), the absolute trauma numbers slightly decreased, a finding probably related to government restrictions and

Table 1. Consensus Statement of the Saudi Association of Neurological Surgery on Triage of Neurosurgery Patients During COVID-19 Pandemic in Saudi Arabia

Priority	Priority 1	Priority 2	Priority 3	Priority 4
Time frame	Immediate and within 24 hours	Within 1 week	From 1 to 4 weeks	>4 weeks
Definition	Immediate: acute life-threatening case that has to be immediately attended to* Within 24 hours: life or significant functional loss that can be saved by intervention within 24 hours†	Life or significant functional loss that can be saved by intervention within 1 week	Life or significant functional loss that can be saved by intervention within 4 weeks	Cases in which life or significant function would not be affected by waiting for >4 weeks
Procedures	**Trauma:** Acute traumatic brain injury with surgical epidural hematoma or SDH Increased ICP uncontrollable by medical/critical care management Insertion of external ventricular drain or ICP monitoring for severely injured patients Chronic SDH associated with neurologic deficits Open depressed skull fracture **Spine:** Acute progressive neurologic deficits interfering with the ability to function in daily life from trauma, tumor, infection, and other compressive diseases **Oncology:** All intracranial tumors affecting level of consciousness or causing hemodynamic instability by increased ICP, hydrocephalus, or herniation* Tumors causing acute visual loss caused by optic nerve/chiasm compression **Vascular:** Acute stroke thrombectomy* Coiling or clipping of a ruptured saccular aneurysm with subarachnoid hemorrhage Craniotomy or embolization of a ruptured AVM with prenidal/nidal aneurysms Decompressive craniectomy or hematoma evacuation* **Pediatrics:** Cases of acute high ICP from hydrocephalus or mass effect Shunt Malfunction/infection Open neural tube defect (encephalocele, myelomeningocele)† **Infections:** Symptomatic intracranial or hardware infections **Functional and epilepsy:** Hardware replacement (ITP, VNS, and IPG) for malfunction, infection, or out of service when associated with symptoms or signs of therapy/ medications' debridement **Peripheral nerve:** Nerve repair for open sharp cut (clean) nerve injuries Debridement and nerve tagging for open contaminated nerve injuries	**Spine:** Subacute progressive neurologic deficit (developed over a few weeks) because of degeneration, trauma, or tumors Spinal instability without neurologic deficit because of trauma, tumor, or infection Suspected cancer or infection that needs biopsy or resection **Oncology:** High-grade primary brain tumors Resection or biopsy for metastatic brain lesions All intracranial brain tumors causing acute or subacute progressive neurologic deficits and/or aggressive radiologic features **Vascular:** Complex ruptured intracranial aneurysm requiring special preparation or equipment **Functional and epilepsy surgery:** Hardware replacement (ITP, VNS, and IPG) because of infection or malfunctioning or nonfunctioning devices, not associated with symptoms or signs of therapy or medications' debridement **Peripheral nerve surgery:** Malignant peripheral nerve sheet tumor	**Spine:** Higher (worsening) chronic neurologic deficit or spinal instability (developed over a few weeks) caused by degeneration, trauma, or tumors **Oncology:** Newly diagnosed low-grade primary brain tumors Intracranial tumors with slowly progressive symptoms related to mass effect and/or radiologic growth **Vascular:** Ruptured AVM with no nidal aneurysms High-grade dural arteriovenous fistulae with intracranial hemorrhage Carotid revascularization (endarterectomy or stenting) for symptomatic carotid stenosis **Pediatrics:** Hydrocephalus with chronically increased ICP Craniosynostosis with evidence of high ICP **Functional and epilepsy surgery:** Medically intractable severe epilepsy requiring urgent surgical intervention Elective replacement of implants (ITP, VNS, and IPG)	Any neurosurgical procedure that can be delayed for >1 month The patient's condition requires re-evaluation on a regular basis and the priority changes depending on the change in the condition

Prioritization of neurosurgical cases based on color domains and priority categories.
SDH, subdural hematoma; ICP, intracranial pressure; AVM, arteriovenous malformation; ITP, intrathecal baclofen pump; VNS, vagal nerve stimulation; IPG, implanted pulse generator.
*Patients cases must be treated as soon as possible.
†Patients can be treated up to or within 48 hours.

Table 2. Patient Characteristics

Variable	Pre-COVID-19 Pandemic (N = 545)	During COVID-19 Pandemic (N = 305)	*P* Value
Age (years), mean (standard deviation)	37.0 (22.5)	34.9 (23)	0.21
Gender			0.1
Male	302 (55.4)	188 (61.6)	
Female	243 (44.6)	117 (38.4)	
Procedures per day, median (IQR)	12 (6—15)	5.5 (3—8)	<0.0001*
Institution type			
Public	398 (73)	212 (69.5)	0.27
Private	147 (27)	93 (30.5)	
Diagnosis category			
Trauma	49 (9)	34 (11.2)	0.31
Oncology	144 (26.4)	88 (28.9)	0.45
Spine	105 (19.3)	58 (19)	0.93
Vascular	78 (14.3)	43 (14.1)	0.93
Congenital	32 (5.9)	11 (3.6)	0.15
Hydrocephalus	60 (11)	44 (14.4)	0.14
Peripheral nerve	29 (5.3)	5 (1.6)	<0.01*
Functional	22 (4)	5 (1.6)	0.06
Infections	26 (4.8)	17 (5.6)	0.61
Priority of the case			
1 (Immediate)	67 (12.3)	63 (20.3)	<0.01*
1 (1—24 hours)	68 (12.5)	57 (18.7)	0.01*
2 (1—7 days)	147 (27)	96 (31.5)	0.16
3 (1—4 weeks)	85 (15.6)	49 (16.1)	0.86
Priority 4 (>4 weeks)	178 (32.6)	41 (13.4)	<0.0001*
Complications			
General	31 (5.7)	11 (3.61)	0.18
Craniospinal	50 (9.17)	28 (9.18)	0.99
Length of hospital stay (days), median (IQR)	7 (4—14)	6 (3—14.5)	0.22
30-day mortality	10 (1.8)	5 (1.6)	0.84

Values are number (%) except where indicated otherwise.
IQR, interquartile range.
*Statistically significant difference.

lockdowns during the pandemic. However, Jose et al.[19] have reported that neurosurgeons believe that the most common reason for performing emergency surgery is trauma, followed by hematoma, and then tumors. Giorgi et al.[31] compared the number of emergency spine surgeries during the pandemic with the same period of the year before. A total of 19 patients were operated on during the pandemic, compared with 10 in the previous year. The investigators have attributed this finding to the structural reorganization of service providers established by the Italian authorities. This effect has also been observed on a larger scale in a comparison of hospitals assigned to emergencies and oncology versus other hospitals in regions heavily affected by the virus. A significant increase in emergencies, including cerebral hemorrhages, trauma, brain tumors, spinal cord compression, hydrocephalus, and strokes, was observed in assigned hospitals. This redistribution of the health care system has led to a significant decrease in neurosurgical cases (both emergency and elective) in nonemergency hospitals.[29]

Despite the decrease in the number of cases during the pandemic, the case distribution between the public and private sectors remained the same, at 70% and 30%, respectively. This ratio is similar to the historical reports of market share between sectors.[32]

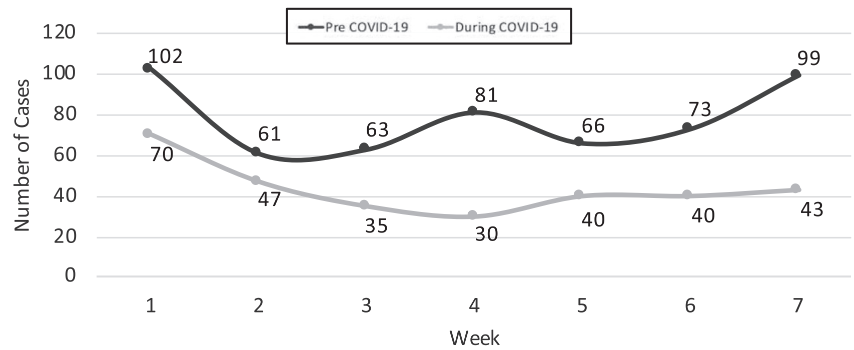

Figure 1. Numbers of surgeries (cases) performed per week before and during the COVID-19 pandemic.

An increase in emergency cases (priority 1) was observed in both sectors; this result reached statistical significance for only the public hospitals. An opposite observation was seen in elective cases (priority 4), which decreased from 26.6% to 4.7% in the public sector, compared with 49% to 33.3% in the private sector. Both decreases were statistically significant. We observed an

Table 3. Univariate and Multivariate Logistic Regression Analysis

	Univariate		Multivariate	
Variable	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Diagnosis category				
Trauma	1.27 (0.80—2.02)	0.31	1.22 (0.76—1.95)	0.41
Oncology	1.13 (0.82—1.54)	0.45	1.18 (0.86—1.62)	0.31
Spine	0.98 (0.69—1.41)	0.93	0.95 (0.64—1.40)	0.77
Vascular	0.98 (0.66—1.47)	0.93	1.08 (0.71—1.64)	0.72
Congenital	0.60 (0.30—1.2)	0.15	0.52 (0.24—1.06)	0.08
Hydrocephalus	1.37 (0.89—2.07)	0.15	1.30 (0.84—2.01)	0.24
Peripheral nerve	0.30 (0.11—0.77)	0.01*	0.29 (0.11—0.78)	0.01*
Functional	0.40 (0.15—1.06)	0.06	0.35 (0.13—0.94)	0.04*
Infection	1.18 (0.61—2.21)	0.61	1.19 (0.63—2.24)	0.60
Priority category				
1 (Immediate)	1.82 (1.25—2.66)	<0.01*	1.82 (1.24—2.67)	<0.01*
1 (1—24 hours)	1.61 (1.10—2.37)	0.02*	1.63 (1.10—2.41)	0.01*
2 (1—7 days)	1.24 (0.91—1.69)	0.16	1.22 (0.89—1.67)	0.21
3 (1—4 weeks)	1.04 (0.71—1.52)	0.85	1.04 (0.71—1.54)	0.83
4 (>4 weeks)	0.32 (0.22—0.47)	<0.001*	0.28 (0.19—0.42)	<0.001*
Institution type				
Public hospitals	0.84 (0.62—1.15)	0.27	0.81 (0.60—1.11)	0.20
Private hospitals	1.19 (0.87—1.62)	0.28	1.23 (0.90—1.69)	0.20
Mortality	0.89 (0.30—2.63)	0.84	0.87 (0.29—2.59)	0.80

Multivariate analysis adjusted for age, gender, and institution type.
OR, odds ratio; CI, confidence interval.
*Statistically significant difference.

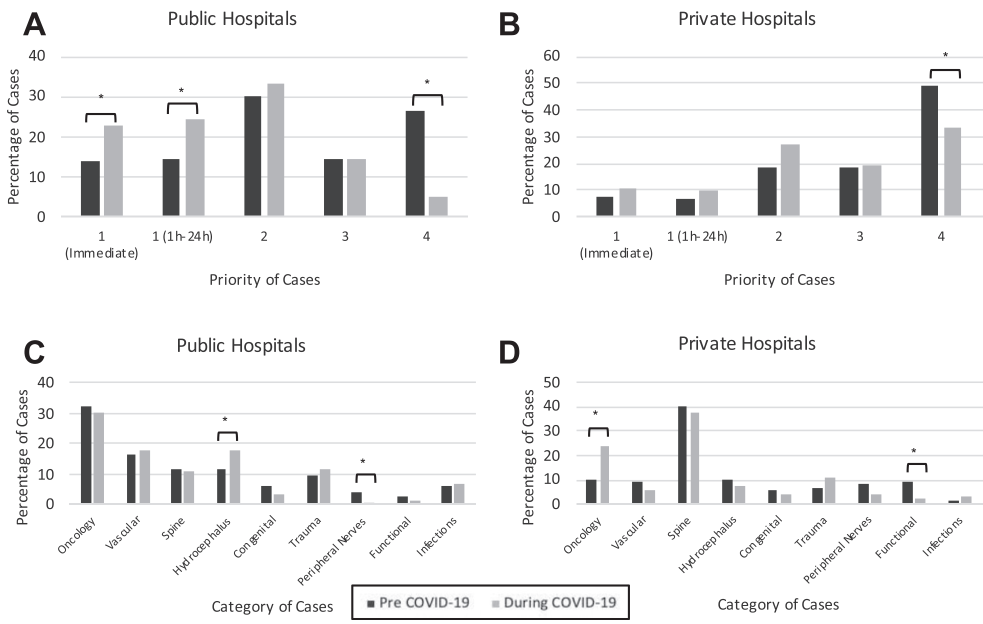

Figure 2. Differences in the percentages of case priority and category between the public and private sectors before and during the COVID-19 pandemic. (**A**) Differences in the percentages of cases by priority before and during COVID-19 in the public sector. The differences in priority 1 (both immediate and within 24 hours) and priority 4 are statistically significant. (**B**) Differences in the percentages of cases by priority before and during COVID-19 in the private sector. The difference in priority 4 is statistically significant. (**C**) Differences in the percentages of cases by category before and during COVID-19 in the public sector. The differences in hydrocephalus and peripheral nerve cases are statistically significant. (**D**) Differences in percentages of cases by category before and during COVID-19 in the private sector. The differences in oncologic and functional cases are statistically significant.

increase in the rate of oncologic procedures performed in private hospitals during the pandemic. This finding might have been caused by the greater ratio of elective oncologic procedures performed in private hospitals than in public hospitals (Figure 2). Jean et al.[20] compared self-reported personal views in the changes preferred by neurosurgeons working in nonprofit practice (including government employment) versus profit practice (including private practice). Only 5% of surgeons in nonprofit practice, compared with 17% of surgeons in profit practice, believed that postponement of elective surgeries and clinical visits should be left to the surgeon's discretion. In contrast, 65% of nonprofit practice surgeons preferred to postpone all elective surgeries and clinical visits, compared with 54% of profit practice surgeons.

Limited information in the literature is available regarding the outcomes of neurosurgical procedures performed during the COVID-19 pandemic. In general, the reported increases in mortality and morbidity in surgical patients during outbreaks are linked to the disease itself, limited resources, and limited information about the disease.[17,33-35] In the early period of the COVID-19 outbreak, multiple reports indicated high morbidity and mortality in surgical cases.[34,35] Lei et al.[35] reported on a Wuhan hospital's experience with 34 patients who underwent surgical treatment and who were confirmed to have COVID-19 after surgery. Forty-four percent of patients required admission to the intensive care unit because of COVID-19–related symptoms, and the mortality was 20.5%, which was related to COVID-19 complications. In another report of 5 patients with chronic subdural hematoma, all of whom were COVID-19 positive, the mortality was 80%; 3 of these patients underwent surgical evacuation under general anesthesia, and 1 patient underwent endovascular embolization for the middle meningeal artery. The only survivor was the patient treated conservatively.[33] In our report, we observed no significant differences in complication and mortality, which were 15% and 1.8% during COVID-19, compared with 14% and 1.6% before the pandemic. The first case reported in Saudi Arabia by the Ministry of Health was on March 2, 2020, and this number increased to 1000 cases by March 26, 2020.[36] As of May 20, 2020, Saudi Arabia had more than 50,000 cases and was ranked fifteenth in total number of infections among countries worldwide. The rate of testing was 18,307 per million individuals in the population, and 10% of tested individuals were confirmed positive. The incidence of infection was 1800 cases per million people (the world average is 655 cases per million people).[37] Saudi Arabia was one of the earliest countries to enforce strict proactive measures, which went into effect on March 9, 2020.[38-40] At the time of this report, the full capacity of ventilators had not been used, thus indicating a stable health care system.[41,42]

All our patients were evaluated preoperatively with the COVID-19 screening system nationally proposed by the Ministry of Health.[43] Among our patients, 20.3% ($n = 62/305$) underwent COVID-19 testing before surgery. All were confirmed as negative preoperatively, except for 1 COVID-19– positive patient who was asymptomatic and had a recent history of admission to another hospital. The patient underwent an endoscopic endonasal approach for frontal sinus lesion and had no complications. Our relatively low rates of complications and mortality relative to those in the previous reports are probably related to the low number of infected patients in our report. None of the surgical team members was diagnosed with COVID-19. This finding is in concordance with a recent survey of 486 members of the Latin American Federation of Neurosurgical Societies, which has reported an infection rate of 0.8% (6% underwent COVID-19 testing).[19]

Our report has several limitations, including the retrospective nature of the study. Another limitation is that Saudi Arabia's infection rates during the early phase of the COVID-19 pandemic were low compared with those of other countries. Furthermore, the capacity of the Saudi health care system was not overloaded with pandemic cases, thus making these results difficult to translate to other countries and regions with different numbers of infections and infection rates. Although data were collected from many participating centers, all neurosurgical centers across the country were not included. This report focused on neurologic surgeries; further studies are required to determine whether COVID-19 has any effects on other specialties.

CONCLUSIONS

We quantitatively evaluated how the COVID-19 pandemic has affected a critical field, neurosurgery. During the early phases of the COVID-19 pandemic, the overall number of neurosurgical procedures declined. The distribution of procedures remained unchanged among major neurosurgical subspecialty services. We observed minor differences in case type when comparing the public and private sectors. In general, the load of neurosurgery emergency procedures performed remained the same, thus highlighting the need to allocate sufficient resources to cover emergencies. More importantly, performing neurosurgical procedures during the pandemic in regions with limited effects of the outbreak on the health care system was safe for both patients and surgical team members. Our findings may aid in the development of guidelines on acute and long-term care during pandemics in surgical subspecialties.

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