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Does COVID-19 Affect Survival and Functional Outcome in Emergency and Urgent Neurosurgical Procedures? A Single-Center Prospective Experience During the Pandemic

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■ **OBJECTIVE:** To assess organizational and technical difficulties of neurosurgical procedures during the coronavirus disease 2019 (COVID-19) pandemic and their possible impact on survival and functional outcome and to evaluate virological exposure risk of medical personnel.

■ **METHODS:** Data for all urgent surgical procedures performed in the COVID-19 operating room were prospectively collected. Preoperative and postoperative variables included demographics, pathology, Karnofsky performance status (KPS) and neurological status at admission, type and duration of surgical procedures, length of stay, postoperative KPS and functional outcome comparison, and destination at discharge. We defined 5 classes of pathologies (traumatic, oncological, vascular, infection, hydrocephalus) and 4 surgical categories (burr hole, craniotomy, cerebrospinal fluid shunting, spine surgery). Postoperative SARS-CoV-2 infection was checked in all the operators.

■ **RESULTS:** We identified 11 traumatic cases (44%), 4 infections (16%), 6 vascular events (24%), 2 hydrocephalus conditions (8%), and 2 oncological cases (8%). Surgical procedures included 11 burr holes (44%), 7 craniotomies (28%), 6 cerebrospinal fluid shunts (24%), and 1 spine surgery (4%). Mean patient age was 57.8 years. The most frequent clinical presentation was coma (44 cases). Mean

KPS score at admission was 20 ± 10 , mean surgery duration was 85 ± 63 minutes, and mean length of stay was 27 ± 12 days. Mean KPS score at discharge was 35 ± 25 . Outcome comparison showed improvement in 16 patients. Four patients died. Mean follow-up was 6 ± 3 months. None of the operators developed postoperative SARS-CoV-2 infection.

■ **CONCLUSIONS:** Standardized protocols are mandatory to guarantee a high standard of care for emergency and urgent surgeries during the COVID-19 pandemic. Personal protective equipment affects maneuverability, dexterity, and duration of interventions without affecting survival and functional outcome.

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus is still raging worldwide. Health care systems all over the world have to cope with COVID-19, with hospitals being forced to reorganize and direct their resources, in terms of both medical personnel and equipment, to dedicated COVID-19 units.¹ Many departments reduced their activity; this

Key words

- COVID-19
- Neurosurgery
- Neurosurgical outcome
- SARS-CoV-2 infection
- Urgent surgery

Abbreviations and Acronyms

- BH:** Burr hole
- COVID-19:** Coronavirus disease 2019
- CSF:** Cerebrospinal fluid
- KPS:** Karnofsky performance status
- LOS:** Length of stay
- OR:** Operating room

PPE: Personal protective equipment

SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2

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was especially true for surgical departments: elective surgeries were canceled or rescheduled, while emergent surgeries were performed under selective indications and following standardized protocols.²⁻⁵

In Italy, Lombardy, in northern Italy, was the first and most affected region by the COVID-19 pandemic in 2020. Our university hospital in Milan was organized as a COVID-19 hub, admitting SARS-CoV-2-positive patients with clinical and surgical disorders.⁶ In this setting, elective surgeries for SARS-CoV-2-positive patients with neurosurgical pathologies were waived until a COVID-19-negative result was obtained; consequently, the overall elective caseload of our division was reduced by Italian and regional regulations and laws. However, urgent surgical procedures were guaranteed through a dedicated COVID-19 operating room (OR). In the present study, the outcome of all urgent and emergency neurosurgical procedures was analyzed and reported. This study also addressed considerations regarding organizational and technical surgical difficulties and their possible impact on survival and functional outcome and analyzed the virological exposure risk of medical personnel.

MATERIALS AND METHODS

Ethical approval was waived by the local Ethics Committee of the University of Milan because all the procedures being performed were part of routine care. We prospectively collected data from our electronic database for all urgent surgical procedures being performed in the COVID-19-dedicated OR. The following preoperative and postoperative variables were gathered: demographics, pathology, Karnofsky performance status (KPS) and neurological status at admission, surgical procedure types and their duration, hospital length of stay (LOS), KPS at discharge (postoperative KPS) and functional outcome comparison, and discharge destination.

We defined 5 classes of pathologies: traumatic, oncological, vascular, infection, and hydrocephalus. The KPS score at admission was calculated and registered for all patients enrolled in the study. Neurological impairment at admission was defined as 1) mild, in patients with slight cognitive impairment without focal neurological deficits; 2) severe, in patients with focal neurological deficits; 3) coma, in patients with a Glasgow Coma Scale score <9. Surgical procedures were placed in 4 categories: burr hole (BH), craniotomy, cerebrospinal fluid (CSF) shunting (including external ventricular drain, ventriculoperitoneal shunt, and shunt revision), and spine surgery.

Functional outcome was classified as improved, unchanged, and worsened based on preoperative and postoperative KPS score. The discharge destination was identified as follows: 1) home, 2) rehabilitation, 3) hospice, and 4) deceased.

The risk of virological exposure of operators was assessed. The appearance of COVID-19 typical symptoms in association with SARS-CoV-2 nasopharyngeal swab positivity was collected during the 10 days following the surgical procedure.

Management of COVID-19 Patients in Our COVID-19 Hub and COVID-19 OR Organization

Our COVID-19 hub was organized so that patients with possible SARS-CoV-2 infection were screened by telehealth: a trained

physician delivered a questionnaire regarding COVID-19-related symptoms and their severity to paramedics by telephone.⁷ Patients with more severe COVID-19 symptoms were admitted to the emergency department, where they underwent a molecular nasopharyngeal swab test and waited for the result in a dedicated area called the gray zone. Patients with a negative swab received standard care with no COVID-19 protocols, while patients with a positive swab were transferred to the COVID-19 ward, which was organized into 3 levels of severity: green, yellow, or red. Patients in critical condition requiring intubation underwent nasopharyngeal swab and a bronchoalveolar lavage. In case of emergency and urgent surgeries, patients were operated on in a dedicated COVID-19 OR. This OR was a negative pressure surgical room set up in the emergency department. All medical personnel wore specific personal protective equipment (PPE). Disposable medical protective uniforms and shoe coverings were available before entering the COVID-19 OR. Operators had to wear 2 pairs of latex or nitrile gloves, an N95 medical protective mask with a surgical mask over it, a surgical cap, and a plastic face shield. According to published surgical guidelines, procedures at risk for aerosolizing viral particles, such as high-speed drilling, were limited.⁸ The medical personnel left the OR via a separate clean pathway only after removing PPE according to a standardized protocol. To avoid undesirable contamination after surgery, instructions about the correct disposal of PPE were displayed and followed.

Statistical Analysis

Quantitative data were tested for normality. Normal variables were reported as mean \pm SD and compared by Student *t* test. Categorical variables were reported as absolute counts (percentages), and intergroup comparison was computed using Fisher exact test or χ^2 test. For all hypotheses, *P* values < 0.05 were considered statistically significant.

RESULTS

We prospectively collected data of 25 emergency and urgent surgical procedures of SARS-CoV-2-positive patients performed at our institution in the COVID-19-dedicated OR. Patient population characteristics are summarized in **Table 1**. Preoperative and postoperative variables for each patient are presented in **Tables 2** and **3**. Complications are reported in **Table 4**.

We identified 11 traumatic cases (44%), 4 infection cases (16%), 6 vascular cases (24%), 2 hydrocephalus cases (8%), and 2 oncological cases (8%). The surgical procedures included 11 BHs (44%), 7 craniotomies (28%), 6 CSF shunts (24%), and 1 spine surgery (4%). The mean age of patients was 57.8 years, and 7 patients were female. The most frequent clinical presentation was coma (11 patients, 44%), followed by severe neurological impairment (8 patients). The mean KPS score at admission was 20 ± 10 , mean surgery duration was 85 ± 63 minutes, and mean LOS was 27 ± 12 days. Seven patients were discharged to home, 13 patients were transferred to a rehabilitation center, and 1 patient was transferred to a hospice. The mean KPS score at discharge for these patients was 35 ± 25 . The outcome comparison was improved for 16 patients and unchanged for 5 patients. Four patients in our series died. The mean follow-up was 6 ± 3 months.

Table 1. Patient Characteristics

	Prevalence	Preoperative KPS	Surgery Duration (minutes)	LOS (days)	Postoperative KPS	Complications*	FU (months)
Pathologies							
Traumatic	11	20 ± 15	90 ± 65	19 ± 11	40 ± 30	7	5 ± 2
Infection	4	20 ± 15	66 ± 26	44 ± 17	40 ± 15	4	5 ± 3
Oncological	2	20	142 ± 158	23	30	2	6
Vascular	6	10	65 ± 47	34 ± 5	15 ± 15	6	8 ± 2
Hydrocephalus	2	10	105 ± 64	12	50	2	12
Surgical procedure							
BH	11	25 ± 15	55 ± 31	27 ± 17	45 ± 25	7	4 ± 3
Craniotomy	7	15 ± 10	155 ± 68	30 ± 8	40 ± 20	7	5 ± 3
CSF shunting	6	10	60 ± 46	26 ± 11	40 ± 10	6	9 ± 3
Spine surgery	1	30	80	38	30	1	9

KPS, Karnofsky performance status; LOS, length of stay; FU, follow-up; BH, burr hole; CSF, cerebrospinal fluid.
*Number of patients with any complication type (see Table 4 for more information).

Pathology Types

Traumatic. The 11 traumatic cases included 8 chronic subdural hematomas (73%), 1 acute subdural hematoma (9%), 1 acute epidural hematoma (9%), and 1 gunshot brain injury (9%). The mean age of trauma patients was 66 ± 19 years, and 7 (64%) were male. The majority of patients experienced mental deterioration (6 of 11, 54.5%), and the mean KPS score at admission was 20 ± 15. The most common surgical procedure performed was BH (7 of 11, 64%). The mean surgery duration was 90 ± 65 minutes, and the mean LOS was 19 ± 11 days. Most patients were referred to a rehabilitation facility (6 of 11, 55%) with a mean KPS score of 40 ± 30. The patient with acute subdural hematoma died.

Infection. Surgery was performed for infectious conditions in 4 patients: 3 brain abscesses (75%) and 1 lumbar epidural empyema (25%). The mean age of patients was 67 ± 9 years, and all patients were male. The mean KPS score at admission was 20 ± 15. Severe neurological impairment was evident at the first clinical examination in 3 patients (75%). Guided navigation drainages through a BH were used for 2 patients (50%) with brain abscesses, while the third patient underwent surgical evacuation through a craniotomy. The patient with an epidural empyema underwent a lumbar laminectomy. The mean surgery duration was 66 ± 26 minutes, and the mean LOS was 44 ± 17 days. Three patients (75%) needed a postoperative hospitalization for rehabilitation. The patient who received the craniotomy was discharged to home. The mean KPS score at discharge was 40 ± 15.

Oncological. The single oncological case concerned a patient with a voluminous cystic intra-axial lesion (anaplastic astrocytoma, IDH wild-type, grade III World Health Organization); the patient underwent surgical drainage of the cystic component in emergency conditions and underwent a craniotomy the following day for surgical resection. The KPS score at admission was 20. The mean duration of the surgical procedures was 142 ± 158 minutes. The LOS was 23 days, during which temozolomide was administered

when the patient tested negative for SARS-CoV-2. The temozolomide was stopped after 3 days because the patient was found to be SARS-CoV-2 positive again. The patient was discharged to home in a stable condition (KPS score 30).

Vascular. There were 6 cerebrovascular cases: 2 subarachnoid hemorrhages from aneurysmal rupture, 2 cerebellar hemorrhages, and 2 intracerebral hemorrhages. The mean age was 55 ± 9 years. Half of the patients were males (3 of 6, 50%). All patients were comatose at admission (KPS score 10). Four patients (66.6%) were subjected to a ventricular shunting procedure, and 2 (33.4%) underwent craniotomy. The mean surgery duration was 65 ± 47 minutes, and the mean LOS was 34 ± 5 days. Three of the patients were moved to a rehabilitation facility, with a mean KPS score of 15 ± 15, and 3 patients died.

Hydrocephalus. The last 2 surgical procedures concerned a 1-year-old male patient, who underwent 2 shunting procedures for ventriculoperitoneal shunt malfunction. Before either procedure, the patient was comatose (KPS score 10). The mean duration of surgeries was 105 ± 64 minutes. After 12 days in the pediatric ward, the patient was discharged to home with a KPS score of 50.

Surgical Procedures

Burr Hole. The mean age of patients who underwent BH was 73 ± 13 years, and 7 patients (64%) were male. This procedure was more frequently performed on patients with mental deterioration (6 of 11, 55%) at admission and a mean KPS score of 25 ± 15. The mean surgical time was 55 ± 31 minutes. The mean LOS was 27 ± 17 days, and rehabilitation was deemed necessary for the majority of patients (8 of 11, 73%). The mean postoperative KPS score was 45 ± 25.

Craniotomy. Craniotomy was more commonly performed for patients who were comatose at admission (5 of 7, 71%), with a mean KPS score of 15 ± 10. These patients were 53 ± 12 years old on

Table 2. Preoperative Variables

Patient	Age (years)/Sex	Type of Pathology	Pathology	Type of Surgery	Preoperative Neurological Status	Preoperative KPS
1	47/F	Trauma	CSDH	BH	Confused, hemisyndrome	50
2	57/M	Trauma	CSDH	BH	Aphasic, hemisyndrome	40
3	60/M	Infection	Brain abscess	Craniotomy	Aphasic, hemisyndrome	40
4	81/F	Trauma	CSDH	BH	Aphasic, hemisyndrome	40
5	1/M	Hydrocephalus	Obstructive hydrocephalus	CSF shunting	Coma	10
6	1/M	Hydrocephalus	Shunt malfunction	CSF shunting	Coma	10
7	75/M	Infection	Brain abscess	BH	Aphasic, hemiparetic, seizures	10
8	75/M	Infection	Brain abscess	BH	Aphasic, hemiparetic, seizures	10
9	57/M	Oncology	HGG	BH	Hemisyndrome	20
10	57/M	Oncology	HGG	Craniotomy	Hemisyndrome	20
11	83/M	Trauma	CSDH	BH	Aphasic, hemisyndrome	30
12	83/M	Trauma	CSDH	BH	Aphasic, incoming seizures	10
13	83/M	Trauma	CSDH	BH	Aphasic, incoming seizures	10
14	78/F	Trauma	CSDH	BH	Confused, hemisyndrome	30
15	82/F	Trauma	CSDH	BH	Aphasic, hemisyndrome	30
16	52/M	Vascular	Cerebellar hemorrhage	CSF shunting	Coma	10
17	50/F	Vascular	SAH	CSF shunting	Coma	10
18	58/M	Infection	Lumbar epidural empyema	Spinal surgery	Paraparesis	30
19	33/M	Trauma	Gunshot brain injury	Craniotomy	Coma	10
20	59/M	Vascular	Cerebellar hemorrhage	CSF shunting	Coma	10
21	49/M	Trauma	AEH	Craniotomy	Coma	10
22	71/F	Vascular	ICH	Craniotomy	Coma	10
23	54/F	Vascular	SAH	CSF shunting	Coma	10
24	45/M	Vascular	ICH	Craniotomy	Coma	10
25	54/M	Trauma	ASDH	Craniotomy	Coma	10

KPS, Karnofsky performance status; F, female; CSDH, chronic subdural hematoma; BH, burr hole; M, male; CSF, cerebrospinal fluid; HGG, high-grade glioma; SAH, subarachnoid hemorrhage; AEH, acute epidural hematoma; ICH, intracerebral hemorrhage; ASDH, acute subdural hematoma.

average, and 6 of 7 were male. The mean duration of surgical procedures was 155 ± 68 minutes, and the mean LOS was 30 ± 8 days. Two patients were discharged to home, 1 patient was transferred to a rehabilitation facility, and 1 patient was transferred to a hospice. The mean KPS score at discharge was 40 ± 20 . Three patients in this group died.

CSF Shunting. CSF shunting procedures were performed in 6 patients with a mean age of 36 ± 27 years, and the male-to-female ratio was 4:2. Coma was the clinical presentation for all 6 patients (KPS score 10). The mean surgical duration was 60 ± 46 minutes, and the mean LOS was 26 ± 11 days. Three patients were discharged to home, and 2 were referred to rehabilitation centers. The mean KPS score at discharge was 40 ± 10 . One patient died.

Spinal Surgery. One patient underwent a lumbar laminectomy to drain an epidural empyema. The patient was a 58-year-old man

who was admitted to the emergency department with a mild paraparesis (Medical Research Council muscle strength scale = 3/5), with a KPS score of 30. He was referred to a rehabilitation facility in stable neurological condition after a 38-day LOS.

Statistical Analysis

The LOS after surgery was statistically longer among infectious diseases cases ($P = 0.01$). Chances to be discharged to home were statistically higher in oncological cases ($P = 0.03$) and non-hemorrhagic hydrocephalus ($P = 0.03$). The KPS score at discharge was statistically improved compared with preoperative score (20 ± 10 vs. 35 ± 25 ; $P < 0.001$).

DISCUSSION

Lombardy is the most populated region in Italy and one of the most affected by the COVID-19 pandemic. Therefore, the health

Table 3. Postoperative Variables

Patient	Surgery Time (minutes)	LOS (days)	Discharge Destination	KPS at Discharge	OC	FU (months)
1	60	6	Home	100	Improved	3
2	85	14	Home	90	Improved	4
3	95	22	Home	60	Improved	3
4	135	9	Home	50	Improved	8
5	60	12	Home	50	Improved	12
6	150	12	Home	50	Improved	12
7	50	57	Rehabilitation	30	Improved	3
8	40	57	Rehabilitation	30	Improved	3
9	30	23	Rehabilitation	30	Improved	6
10	254	23	Rehabilitation	30	Improved	6
11	30	23	Rehabilitation	30	Unchanged	2
12	35	23	Rehabilitation	30	Improved	2
13	30	23	Rehabilitation	30	Improved	2
14	45	23	Rehabilitation	30	Unchanged	4
15	60	39	Rehabilitation	30	Unchanged	10
16	60	25	Rehabilitation	30	Improved	8
17	26	35	Rehabilitation	30	Improved	8
18	80	38	Rehabilitation	30	Unchanged	9
19	210	28	Home	50	Improved	3
20	46	35	Rehabilitation	30	Improved	3
21	95	25	Hospice	10	Unchanged	6
22	80	—	—	—	Deceased	—
23	25	—	—	—	Deceased	—
24	150	—	—	—	Deceased	—
25	200	—	—	—	Deceased	—

LOS, length of stay; KPS, Karnofsky performance status; OC, outcome comparison; FU, follow-up.

care system in Lombardy was reorganized following the hub-and-spoke organizational model.⁶ A few hub centers accounting for specific pathologies and medical specialties were defined, while the remaining centers served as spokes referring patients to the hubs and managing patients with COVID-19 of low or intermediate severity. Our institution was a COVID-19 hub managing medical and surgical patients with highly severe COVID-19. In this environment, our neurosurgical unit limited elective surgeries to cases that could not be deferred and referred most of the non-COVID-19 traumatic and oncological cases to neurosurgical trauma and oncology hubs.

We identified 25 SARS-CoV-2–positive surgical patients who underwent emergency and urgent surgeries in the dedicated COVID-19 OR. Although our sample population was small, paucity of data from available literature of systematically organized COVID-19 neurosurgical urgent case series might make this study useful to improve the management of such patients during this harsh pandemic that shows no signs of ending.^{9–11}

Traumatic Cases

Traumatic cases were the most common, including 8 chronic subdural hematomas, 1 acute subdural hematoma, and 1 epidural hematoma. The prevalence of posttraumatic pathologies related to minor trauma could be explained by restricted mobility and outdoor activity, consequent to Italian government restrictions being imposed to limit the pandemic. Patients with posttraumatic pathologies showed the highest COVID-19 positivity rate. As trauma is the most common reason for emergency department admittance, these patients were more frequently subjected to nasopharyngeal swab testing.

Infection Cases

Patients with infectious pathologies frequently showed a serious clinical impairment requiring urgent or emergency treatment. Moreover, they spent more days in the hospital after surgery, which could be related to the need for long-term use of antibiotics that could not be administered at home.

Table 4. Patient Complications

Patient	Type of Complication				
	COVID-19	Infectious	Surgical	Neurological	Others
1	—	—	—	—	—
2	—	Phlebitis	—	—	—
3	PE	Bacterial pneumonia	—	—	Hyperglycemia
4	—	—	—	—	—
5	—	—	Shunt malfunction	Coma	—
6	—	—	—	Drug-resistant seizures	—
7	Pneumonia	Bacterial pneumonia	New drainage	Drug-resistant seizures	—
8	Pneumonia	Sepsis	—	—	—
9	Pneumonia	Bacterial pneumonia	—	—	Hyponatremia
10	Persistent positivity	Fever	—	—	—
11	—	—	CSDH relapse	Worsening hemiparesis	—
12	—	—	—	Drug-resistant seizures	—
13	—	—	—	—	—
14	—	—	—	—	—
15	—	Multidrug resistant bacterial colonization	—	—	AF
16	—	Bacterial pneumonia	—	—	—
17	—	Bacterial pneumonia	—	Hydrocephalus	—
18	—	Spondylodiscitis	Arthrodesis	—	Pleural effusion
19	—	Bacterial pneumonia	—	—	—
20	ARDS, DVT	—	—	—	—
21	—	Sepsis	—	—	HRS
22	—	—	—	—	Death
23	—	—	—	—	Death
24	—	—	—	—	Death
25	—	—	—	—	Death

COVID-19, coronavirus disease 2019; PE, pulmonary embolism; CSDH, chronic subdural hematoma; AF, atrial fibrillation; ARDS, acute respiratory distress syndrome; DVT, deep venous thrombosis; HRS, hepatorenal syndrome.

Oncological Cases

The treatment of oncological disease in SARS-CoV-2–positive patients was delayed until patients became SARS-CoV-2 negative in most of our case series in 2020. Therefore, the oncological patient in the current study was not expected to survive without surgery (American Society of Anesthesiologists class V). The patient experienced a COVID-19 relapse after temozolomide administration. Again, COVID-19 presents physicians with an ethical difficulty. On one hand, is it right to administer chemotherapy, exposing oncological patients to the risks of COVID-19 relapse? On the other hand, is it right not to administer the only medical treatment available for patients with high-grade glioma because of the risk of COVID-19 relapse? The data present in the literature are too scarce to answer these questions,

confirming the need to fill the gaps with further clinical experiences.¹²

Vascular Cases

The cerebrovascular disease group was the second most represented in our series. Considering that only a small percentage of patients with cerebrovascular disorders require neurosurgical treatments, we are considering here only the tip of an iceberg that is composed of a multitude of patients with ischemic stroke or with hemorrhagic brain diseases not amenable to neurosurgical treatment (e.g., subarachnoid hemorrhages and intracerebral hemorrhages, often amenable to medical and endovascular treatments). Therefore, in agreement with a recent systematic review, cerebrovascular events are relatively common findings during the

COVID-19 pandemic, with SARS-CoV-2 infection appearing to help trigger the vascular event.¹³ We registered the highest death rate among these patients. However, this is likely to be attributable to the deadly nature of cerebrovascular diseases rather than surgical treatment; all the deceased patients were comatose at admission.

CSF Shunting

CSF shunting procedures seemed to be the least influenced by the COVID-19 setting protocols. A possible explanation could be that patients needing an urgent CSF shunt received an external ventricular drain, which is a procedure with little susceptibility to dexterity limitations of surgical movements, in terms of both operative time and outcome.

Surgery Duration

Overall, the mean duration of the surgeries being performed in the COVID-19—dedicated OR was longer compared with the usual OR setting (data from electronic registers). According to an internal survey conducted in our neurosurgical unit, almost every surgeon reported some difficulties in the COVID-19 OR. Main difficulties concerned reduction in hand dexterity related to multiple pairs of gloves (2 disposable and 1 sterile) and poor visual acuity owing to tarnished face shields. These difficulties persisted in later surgeries and were independent of personal surgical expertise (attendants vs. residents).

Hospital LOS

An increased LOS was reported in this series. Dowlati et al.¹⁴ pointed out that patients with COVID-19 were more likely to develop an in-hospital complication other than the COVID-19 diagnosis. Likewise, about half of the patients in our series presented with an infectious disease complication. We share the impression from previous reports of a greater risk of neurosurgical patients with COVID-19 to experience longer-than-average hospital stay. Nonetheless, major hospitalization-related complications were not observed.

Survival and Functional Outcome

The outcome comparison in this series highlights no worsening of KPS at discharge compared with preoperative KPS. In our experience, the aforementioned technical difficulties imposed by the COVID-19—dedicated OR protocols seem not to have great repercussions on the surgical outcome except for the surgical duration. Moreover, none of the patients in our series died of COVID-19—related causes. Nonetheless, the postoperative functional outcome remains unsatisfactory. We think that it might be mainly attributable to the patient's severity of clinical presentation at admission (e.g., the high percentage of comatose patients).

Virological Risk for Medical Personnel

None of the operators developed a postoperative SARS-CoV-2 infection. These reassuring data should increase the confidence

of the health professionals involved in the pandemic: compliance with safety protocols is fundamental and effective in safeguarding their health.

Limitations

The main limitation of this study is the characteristics of the cohort, which is made up of a limited number of heterogeneous patients with serious clinical conditions. Nevertheless, SARS-CoV-2—positive neurosurgical patients are most often operated on with extreme urgency, likely having characteristics comparable to those of this series. Broader sample size is, in any case, desirable to reduce the heterogeneity and selection bias intrinsic to the inclusion of patients with different pathologies and subjected to different surgical procedures. Moreover, the findings of this study should be generalized to other institutions with a similar setting and a comparable experience with the pandemic.

CONCLUSIONS

The current surgical series reports the experience of a dedicated surgical COVID-19 center facing emergency and urgent surgical cases during the active phase of the COVID-19 pandemic. This case series suggests that standardized protocols for referral and in-hospital management are mandatory to guarantee a high standard of care in these emergency cases. For these reasons, neurosurgical COVID-19—positive cases should be referred to specialized centers such as the hubs defined in our region.

PPE affects maneuverability, dexterity, and duration of interventions, according to dedicated surgical team witnesses and electronic registers; nonetheless, survival and overall functional outcome do not seem to be greatly affected by technical concerns. The absence of SARS-CoV-2 infections among the medical personnel is also worthy of being highlighted. Further investigations are needed to clarify the impact of SARS-CoV-2 on the management of urgent neurosurgical procedures.

CRedit AUTHORSHIP CONTRIBUTION STATEMENT

Giorgio Fiore: Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing. **Luigi Gianmaria Remore:** Validation, Data curation, Formal analysis, Writing - original draft. **Leonardo Tariciotti:** Validation, Data curation, Formal analysis, Writing - review & editing, Supervision. **Giorgio Giovanni Carrabba:** Methodology, Validation, Data curation, Writing - review & editing, Supervision. **Luigi Schisano:** Validation, Data curation, Formal analysis, Writing - review & editing, Supervision. **Mauro Pluderi:** Methodology, Validation, Data curation, Writing - review & editing, Supervision. **Giulio Andrea Bertani:** Methodology, Validation, Data curation, Investigation, Writing - original draft, Writing - review & editing, Supervision. **Stefano Borsa:** Methodology, Validation, Data curation, Writing - original draft, Writing - review & editing, Supervision. **Marco Locatelli:** Methodology, Validation, Data curation, Writing - review & editing, Supervision.

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