ORIGINAL RESEARCH

Neurosurgical service during COVID-19 pandemics in Ljubljana, Slovenia- lessons learned

Matic Munda, MD[1], Tomaz Velnar, MD, PhD[1], Borut Prestor, MD, PhD[1], Tilen Zele, MD, PhD[1], Peter Spazzapan, MD[1], Bostjan Matos, MD, PhD[1], Natasa Kos, MD, PhD[2], Mitja Benedicic, MD, PhD[1], Arne Jeglic, MD[1], Igor Tekavcic, MD, MSc[1], Andrej Porcnik, MD[1], Roman Bosnjak, MD, PhD[1]

1. Department of Neurosurgery, University Medical Centre Ljubljana, Ljubljana, Slovenia
2. Department of Rehabilitation, University Medical Centre Ljubljana, Ljubljana, Slovenia

Abstract

Introduction: The novel coronavirus disease 2019 (COVID-19) became an important and urgent threat to global health. In Slovenia, the COVID-19 struck the health system immensely. Neurosurgery experienced difficulties, not only in regular, elective surgeries, but also during emergency situations.

Methods: In the article, we analyse and compare the number of elective and emergency neurosurgical procedures during the time of the pandemic (from March 2018 to February 2020) and describe our protocol in the management of neurosurgical patients in the Medical Centre in Ljubljana, Slovenia.

Results: There were 2597 patients treated surgically, including 1932 emergency patients and 665 emergency patients. Overall, we recorded an 11.2% drop in all neurosurgical procedures in two years after COVID-19 was declared compared to two years before. Elective procedures decreased by 13.9%, mostly on account of spinal pathology procedures (245, 23.5%), functional neurosurgical procedures (37 cases, 24.7%), endonasal endoscopy procedures (11, 12.8%), and brain lesions (31, 4.8%).

Conclusion: COVID-19 had a vast impact on the healthcare system in Slovenia, including on neurosurgery. New and improved strategies to maintain neurosurgical practice during public health emergencies are necessary for the neurosurgical service and healthcare system to run smoothly in the long term and prevent disruptions during future pandemics.

Keywords: COVID-19; neurosurgery; patient management; antivirus protocol; pandemic measures; Ljubljana

doi: https://doi.org/10.55005/v3i1.4

Introduction

COVID-19 is a novel coronavirus disease caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2)[1,2]. Although it primarily affects the respiratory system, other organs, including the brain, may be affected. SARS-CoV-2 was first reported as four cases of pneumonia of unknown etiology on December 29th, 2019, in Wuhan, Hubei Province in China and is responsible for an ongoing pandemic. The disease presented with severe and unique biological characteristics, specific clinical symptoms, and particular blood test results and imaging features[2-4]. As a result of a rapid spread due to high transmissibility, the virus was recognized as a major threat to global health on March 11th 2020, when COVID-19 was declared a pandemic by World Health Organization.

At the time of writing in August 2022, the number of infected patients exceeded 550 million in almost every country around the world. The real number of infected people is in all likelihood much higher. The number of deaths caused by COVID-19 is predicted to be more than 6.4 million[1,5].

The COVID-19 pandemic caused difficulties in every health system. European countries were almost equally affected and adjustments were necessary to provide care for COVID-19 patients and normal functioning of the health system in parallel[6]. The European Union issued recommendations for member states in addressing pandemics. Of course, the European countries differed in their health policies.

Many departmental protocols were implemented, and protective measures were taken to cope with the massive influx of COVID-19 patients while preserving the regular medical services running normally[7,8]. Medical staff, equipment, and material were reallocated; management protocols were created; and dedicated in-hospital routes and operating theatres were established for ill patients[6,9]. Strict control of elective and/or emergency admissions, prevention of intermixing of cases and health care staff, improvements in operation and treatment processes, and strict ward management rules were put into practice[7,9,10]. The conventional outpatient service was altered into a telemedicine outpatient service, and elective surgeries were postponed or stopped. Moreover, some patients with COVID-19 infection had to undergo vital surgery, while others became symptomatic within days of elective surgeries[6,7,10,11].

Slovenia is a central European country with a population of approximately two million inhabitants. There are two neurosurgical centers, one in Ljubljana, the capital city, and the other in Maribor, the second largest city. Both are organized as departments within the Division of Surgery, located at university hospitals. The Department of Neurosurgery at University Medical Centre Ljubljana comprises 50 beds and an intensive care unit, while the one in Maribor is half the size. The Department of Neurosurgery in Ljubljana covers approximately two-thirds of the population, while Maribor covers the rest.

Compared to other European countries, COVID-19 struck our health system immensely. Due to rapid virus spread in Slovenia, it was practically impossible to make substantial timely preparations to minimize the impact of the pandemic and adapt the health system quickly. The official anti-virus measures at the state level were put into action a few days after the first case was confirmed, on March 4th, 2020, and the pandemic was declared a week after[12]. In addition, the general pandemic measures on the state level, including state lockdown, mandatory masks, hand disinfection, testing, and strict border crossing rules, a series of hospital and departmental protocols were instituted to limit the virus spread inside the hospitals and health centers. Some of the measures included adjustments of outpatient services, strict regulations upon patient admission, additional departmental and surgical premises for high-risk or COVID-19 positive patients, quantitative reduction of the surgical program including postponement of elective surgeries, reallocation of staff to COVID-19-related posts, constant use of protective equipment, and expansion of the telephone consultation service. Neurosurgery has also experienced difficulties, not only in regular, elective surgeries but also, especially during emergencies[12,13]. The management of these neurosurgical patients has therefore become more difficult than ever. In the article, we outline the impact that COVID-19 has had on the management of patients at the neurosurgical department in Ljubljana and describe our departmental protocols.

Methods and results

Patient analysis

We analysed and compared the number of elective and emergency surgeries before and during the pandemic. We denote an emergency case as any case that needed immediate surgery in a matter of hours due to a life-threatening situation and an elective case as any case that was scheduled in advance and operated on during working hours. Vital or emergency surgery encompassed any form of an acute brain haemorrhage (subdural, epidural or intracerebral), decompressive craniectomy, insertion of external ventricular drainage or intracranial pressure monitoring and evacuation of a chronic subdural haematoma or vital spinal pathology. For the analysis, we divided the procedures into subgroups: I) spinal pathology (spinal degenerative disorders, spinal lesions), II) brain lesions (any supra- or infratentorial brain tumours, cysts, abscesses or similar pathology), III) ventriculoperitoneal drainage, IV) cranioplasty, V) functional neurosurgical procedure (deep brain stimulation, spinal cord stimulation, vagus nerve stimulation, replacement of the batteries), VI) vascular pathology (aneurysms, arteriovenous malformations, and similar, VII) endonasal endoscopy (pituitary adenoma, Rathke cyst, clivus chordoma, craniopharyngioma).

We analysed the patient number and the pathology two years before the COVID-19 pandemic was declared (from March 2018 to February 2020). During this time, 2924 patients were treated surgically at the Department of neurosurgery in Ljubljana, including 2413 patients who represented elective cases. Overall, 1042 surgeries included spinal pathology, 646 brain lesions, 154 elective ventriculoperitoneal drainages for hydrocephalus treatment, 41 cranioplasties, 150 functional, 62 vascular, 86 endonasal endoscopic and 62 other procedures. There were 681 emergency cases.

During the two years of COVID-19 pandemic, from March 2020 to February 2022, there were 2597 patients treated surgically. Elective procedures included 1932 patients (***Figure 1***).

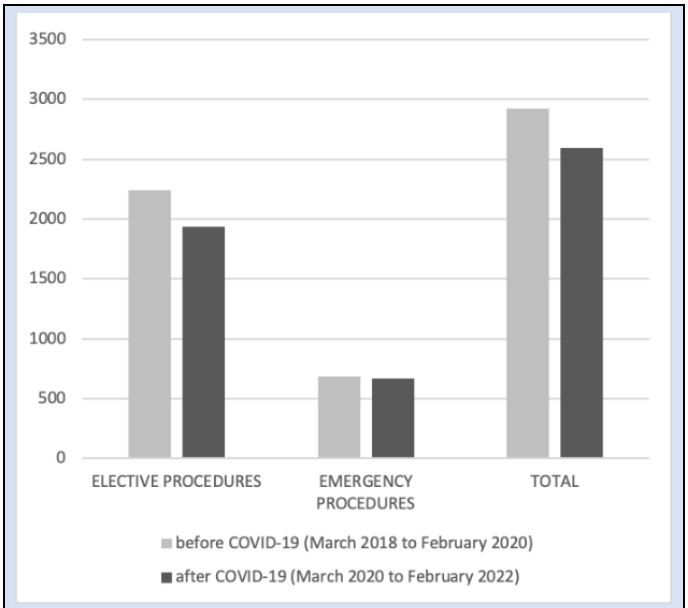

Figure 1. Elective and emergency neurosurgical procedures before and after the COVID-19 pandemic.

There were 797 spinal pathology surgeries, 665 brain lesions, 153 ventriculoperitoneal drainages, 50 cranioplasties, 113 functional, 65 vascular, 75 endoscopic endonasal and 64 other procedures. Emergencies were encountered in 665 cases (***Figure 2***).

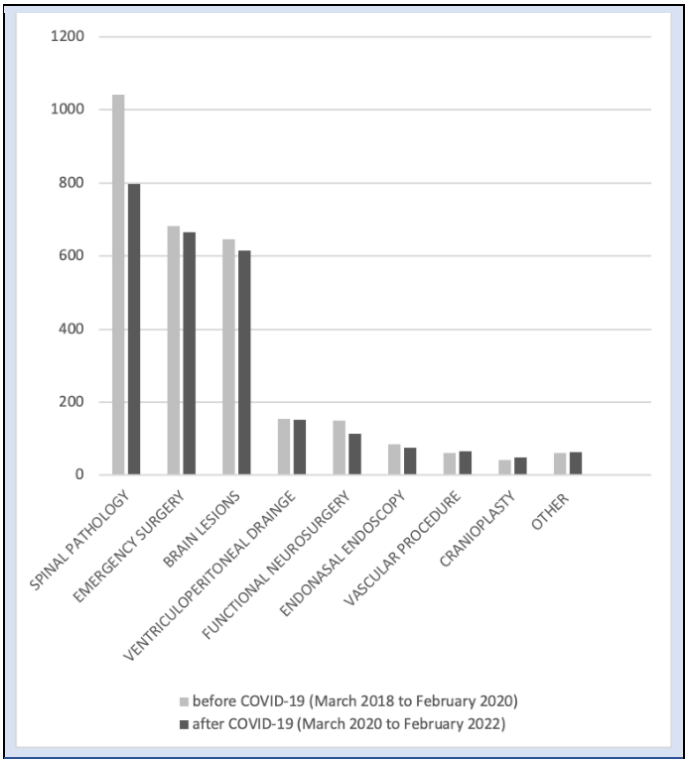

Figure 2. The subgroups of neurosurgical procedures before and after the COVID-19 pandemic.

Overall, we recorded an 11.2% (n=327) decrease in all neurosurgical procedures in two years after COVID-19 was declared compared to two years before. A decrease in elective procedures was 13.9% (n=311), mostly on account of spinal pathology procedures (245, 23.5%), functional neurosurgical procedures (37, 24.7%), endonasal endoscopy procedures (11, 12.8%) and brain lesions (31, 4.8%). The decrease in emergency procedures was insignificant and amounted to a 2.4% drop (n=16) (***Table 1***).

The management protocol in the early phase of the COVID-19 pandemic

The first step included the evaluation and screening of neurosurgical patients who presented for neurosurgical treatment or assessment. In the early phase of the pandemic, the number of positive COVID-19 patients was low. General public measures were set in place: lockdown and limitation of the admission for all urgent patients exclusively through the emergency ward. These patients were managed immediately according to the underlying pathology and simultaneously screened for potential risk of contracting COVID-19 with a nasopharyngeal swab for the rapid antigen test (RAT) initially and then with a nasal swab for the rapid transcriptase-polymerase chain reaction (RT-PCR) test. Imaging, preoperative preparation, and surgical and early postoperative care were performed with all necessary protective measures in positive patients and in those requiring emergent surgical treatment whose COVID-9 status was unknown or unconfirmed at the time of admission. A special isolation area was established where urgent patients were admitted for testing. All emergency, supportive and intensive care hardware was at hand. This area was isolated with no connection to other hospital areas. The initial rapid screening protocol for every patient included body temperature measurement and a detailed COVID-19 screening questionnaire in awake patients. The questionnaire was also administered to patient relatives and attendants, especially in the instances of non-conscious patients, in addition to protective measures such as hand sanitization and face masks.

Elective patients and those requiring non-urgent transfer from other hospitals were screened for potential risk of contracting COVID-19 with the RT- PCR test. They have been provisionally accommodated in so-called transitional zones or specially established holding areas where RT-PCR was performed before surgery. After the test result became available, they were transferred to a regular ward to avoid the potential spread of the virus.

Table 1. Comparison of neurosurgical procedures in a two-year period before and after the COVID-19 pandemic was declared..

Neurosurgical procedure type	Number of cases		Decrease in number of cases
	03.2018 - 02.2020	03.2020 - 02.2022	
Spinal pathology	1042	797	245 (23.5%)
Emergency surgery	681	665	16 (2.4%)
Brain lesions	646	615	31 (4.8%)
Ventriculoperitoneal drainage	154	153	1 (0.7%)
Functional neurosurgery	150	113	37 (24.7%)
Endonasal endoscopy	86	75	11 (12.8%)
Vascular procedure	62	65	/
Cranioplasty	41	50	/
Other	62	64	/
Elective surgery	2243	1932	311 (13,9%)
Emergency surgery	681	665	16 (2.4%)
Total	2924	2597	327 (11.2%)

The management protocol in the late phase of the COVID-19 pandemic

In the later phase of the pandemic, the number the cases rose. The management scheme needed to be adjusted. Therefore, all areas and treated patients were divided into three groups: I) red (danger zone, urgent patients), II) grey (transitional, waiting for the zone, elective patients), and III) green (safe zone, elective patients).The red zone was a high-risk area, comprising the patients with confirmed COVID-19 infection and all vital emergencies transported to the general emergency admission department. These patients required an urgent, lifesaving neurosurgical intervention, regardless of the COVID-19 status, and preventive and protective measures were taken during their treatment. The RAT was used for patients requiring immediate surgery on an emergency basis and the RT-PCR test was performed during the operation to accommodate these patients in suitable postoperative hospital areas. These urgent patients were operated on with full personal protective equipment.

The second, grey, group included all non-urgent and elective patients who were admitted to the neurosurgical department for regular treatment. These patients were either vaccinated or tested in advance (before admission) and were accommodated in grey zones to check their COVID-19 status with RT-PCR. When confirmed virus-negative with RT-PCR, they were transferred to green zones.

The green zone was the safe one, which included COVID-19 negative elective patients. All transfers among these designated hospital and department zones were limited also in terms of personnel, material, and equipment.

All emergency patients underwent this protocol and all admitted patients were categorized based on the degree of emergency for intervention. Those with life-threatening emergencies were operated on immediately, regardless of the COVID-19 status, unless confirmed differently. This was a small group, luckily, and included patients with life-threatening neurosurgical emergencies who were already hospitalised on other hospital wards and were certainly COVID-19 negative when their health condition deteriorated.

The inclusion criteria for emergency surgery encompassed: I) all paediatric and adult patients with features of raised intracranial pressure, like stroke, abscess, tumour, brain oedema, subdural or epidural hematoma, deteriorating hydrocephalus; II) all traumatic cases needing observation or emergency operation; III) all spinal compressive myelopathies (both traumatic and non-traumatic), and IV) vascular emergencies: ruptured intracranial aneurysms, ruptured arteriovenous malformations, intracerebral haematomas.

The urgent cases were triaged according to the complexity of the case, the ability of the anaesthesiology team, the availability of surgical instruments, and the availability of postoperative accommodation (COVID-19/non-COVID-19 emergency rooms).

Urgent patients that could be handled with the existing setup were operated on according to the causal pathology and with all protective measures in the dedicated theatres and postoperatively treated in the designated red zone intensive care units until they were ready for discharge.

Patients with no known exposure to COVID-19 and COVID-19 negative patients, namely the elective patients, semi-urgent patients, and those without acute respiratory signs and symptoms with a normal chest radiograph and negative RT-PCR tests, were considered low-risk. Low-risk patients were operated on in a standard (pre-COVID-19) neurosurgical setting and postoperatively treated in green ICUs or the green ward areas.

Discussion

Despite the difficulties the virus spread has caused to the health system, regular medicine had to work continuously and in parallel with the treatment of COVID-19 patients[13-15]. Therefore, the neurosurgical practice had to be organised according to new rules. The flow of patients to health institutions has increased during the pandemic as the COVID-19 patients have joined patients with everyday health problems. This new reality needed to be addressed adequately and effectively[16,17].

The neurosurgical department in Ljubljana is the largest in Slovenia and addresses all neurosurgical pathology. Due to the constant inflow of patients, it was necessary to limit admissions according to the treatment priority. For this purpose, we have implemented a triage system on the level of the outpatient clinic to minimise patient admission and adapt to the new situation. All emergencies were managed without delay.

When comparing the number of neurosurgical interventions in the two years before and after the COVID-19 pandemic, a relatively small decrease was recorded, amounting to 13.9% elective cases. The drop in cases was most prominent in the fields of spinal pathology and functional neurosurgery since these types of procedures were the least urgent because of the non-malignant nature of pathology in general and the lack of tendency for neurological deterioration. The reduction in surgery for spinal pathology is attributed to fewer surgeries for degenerative spinal disorders with pain syndromes. Cases with accompanying neurological deficits or spinal lesions were operated on as soon as possible when appropriate. The number of procedures in other neurosurgical fields was comparable. There was a small decrease in the number of brain and sellar lesions, which might be coincidental or because patients without acute clinical presentation did not reach adequate health services and did not receive timely appropriate diagnostics for some time during the height of the pandemic.

The decrease in the number of elective surgeries during the pandemic was not as drastic as we predicted it would be. One of the reasons for that was the effective COVID-19 screening protocol. Very few surgeries were postponed on account of a patient being SARS-CoV-2 positive because when a patient presented with a positive test on admission, he or she was rescheduled, returned home, and a substitute patient was called in for the procedure. Another contributing factor might also be that during the quieter periods of the pandemic, when medical staff returned to their original posts, more surgeries were performed to make up for the backlog.

With other SARS-CoV-2 positive patients, if possible, conservative treatment was implied or the patient was rescheduled for the surgery until the contagious period expired.

With these measures, the clinical flow of neurosurgical emergencies was optimised so that the patients were not deprived of immediate neurosurgical intervention. We confirmed this by comparing the number of emergency operations two years before and after the COVID-19 pandemic was declared. In comparison, from March 2018 to February 2020, 681 emergency surgeries were performed and from March 2020 to February 2022, the number of surgeries was 665. Despite the limitations and epidemiological situation, we did not record a significant quantitative decrease in neurosurgical emergency surgeries.

With new triage systems on the level of the outpatient clinic, we optimised patient admission. A nonregulated inflow of patients yields a high risk of the transmission of COVID-19 to patients and hospital staff. In general, SARS-CoV-2 positive patients that undergo surgical intervention have a higher complication and mortality rate than SARS-CoV-2 negative patients[18-21]. COVID-19 is not only associated with a high mortality rate, but also puts an enormous strain on the healthcare system. Severe forms of COVID-19 with respiratory failure led to a high rate of intubation, thus creating a shortage of beds in the intensive care units[14-16]. Therefore, the treatment of other critical diseases became even more difficult and limited. From a neurosurgical perspective, the COVID-19 pandemic forced us to consider that regular neurosurgery needed to continue in parallel with the treatment of COVID-19 and balance these aspects of our everyday work.

As mentioned, special precautions were applied for patients with emergent neurosurgical issues that were COVID-19 positive. These patients were operated on immediately in the COVID-19 operation theatre. The intubation was conducted according to a quick protocol by the anaesthesiologist and the assistant nurse. No other staff were present in the operation theatre at the time of intubation. Then, the surgical staff approached and started the procedure. Personal protective equipment was worn at all times, and institutional protective measures were respected. The equipment and material in the operating theatre were reduced to a minimum. During the surgery, the RT-PCR test was performed to help with the postoperative patient accommodation arrangement. When confirmed positive, patients were further treated in the red zones, which encompassed the COVID-19 intensive care units (ICU) and special areas on the neurosurgical ward. RT-PCR tests were conducted every two days. Sometimes, the patients became COVID positive while hospitalised. In these instances, the patients were transferred to red areas and treated there according to their condition. Extubation was done on the operating table since this minimised the risk for cross-infection and provided ample time for proper operating theatre disinfection. Patients were transferred to the ICU when necessary. Those who were medically stable were treated in the red areas of the neurosurgical ward. They were discharged home when appropriate. In addition to regular precautions, such as minimal drilling and abundant irrigation, we tried to avoid the trans-nasal procedures (for hypophyseal tumours) unless urgent indications (apoplexy, loss of vision) were present. Additionally, clear delineation of roles, a disinfection and aeration plan, cross monitoring of all staff members for potential contamination, and reduction of the number of persons in the theatre at a time is advantageous[20-24].

Conclusions

COVID-19 had a vast impact on the healthcare system in Slovenia, including on neurosurgery. We have attempted to ensure medical services run as normally as possible in our department and others. Management protocols were continuously adapted to the course of the pandemic. New and improved strategies to maintain neurosurgical practice during public health emergencies are necessary for the neurosurgical service and healthcare system to run smoothly in the long term and prevent disruptions during future pandemics.

Disclosures

Conflict of Interest: All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was not sought.

Funding: No funding was received for this research.

Correspondence

Roman Bosnjak

Department of Neurosurgery, University Medical Centre Ljubljana, Zaloska 7, 1000 Ljubljana, Slovenia

+38615223250

roman.bosnjak@kclj.si

Tomaz Velnar

Department of Neurosurgery, University Medical Centre Ljubljana, Zaloska 7, 1000 Ljubljana, Slovenia

+38615223250

tvelnar@hotmail.com

References

1. Haidar MA, Shakkour Z, Reslan MA, Al-Haj N, Chamoun P, Habashy K, et al. SARS-CoV-2 involvement in central nervous system tissue damage. Neural Regen Res. 2022;17(6):1228-1239. doi: 10.4103/1673-5374.327323.
2. Peacock WF, Soto-Ruiz KM, House SL, Cannon CM, Headden G, Tiffany B, et al. Utility of COVID-19 antigen testing in the emergency department. J Am Coll Emerg Physicians Open. 2022;3(1):e12605. doi: 10.1002/emp2.12605.
3. Chams N, Chams S, Badran R, Shams A, Araji A, Raad M, et al. COVID-19: A Multidisciplinary Review. Front Public Health. 2020;8:383. doi: 10.3389/fpubh.2020.00383.
4. Murta V, Villarreal A, Ramos AJ. Severe Acute Respiratory Syndrome Coronavirus 2 Impact on the Central Nervous System: Are Astrocytes and Microglia Main Players or Merely Bystanders? ASN Neuro. 2020;12:1759091420954960. doi: 10.1177/1759091420954960.
5. World Health Organization. WHO Coronavirus (COVID-19) Dashboard (internet). 2022 August (cited 2022 August 24). Available at: https://covid19.who.int (Accessed 22. 11. 2021)
6. Doglietto F, Vezzoli M, Gheza F, Lussardi GL, Domenicucci M, Vecchiarelli L, et al. Factors Associated With Surgical Mortality and Complications Among Patients With and Without Coronavirus Disease 2019 (COVID-19) in Italy. JAMA Surg. 2020;155(8):691-702. doi: 10.1001/jamasurg.2020.2713.
7. Suleyman G, Fadel RA, Malette KM, Hammond C, Abdulla H, Entz A, et al. Clinical Characteristics and Morbidity Associated With Coronavirus Disease 2019 in a Series of Patients in Metropolitan Detroit. JAMA Netw Open. 2020;3(6):e2012270. doi: 10.1001/jamanetworkopen.2020.12270.
8. Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, et al. The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg. 2009;250(2):187-96. doi: 10.1097/SLA.0b013e3181b13ca2.
9. Leira EC, Russman AN, Biller J, Brown DL, Bushnell CD, Caso V, et al. Preserving stroke care during the COVID-19 pandemic: Potential issues and solutions. Neurology. 2020;95(3):124-133. doi: 10.1212/WNL.0000000000009713.
10. Arteaga AS, Aguilar LT, González JT, Boza AS, Muñoz-Cruzado VD, Ciuró FP, et al. Impact of frailty in surgical emergencies. A comparison of four frailty scales. Eur J Trauma Emerg Surg. 2021;47(5):1613-1619. doi: 10.1007/s00068-020-01314-3.
11. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, et al. A global clinical measure of fitness and frailty in elderly people. CMAJ. 2005;173(5):489-95. doi: 10.1503/cmaj.050051.
12. NIJZ Koronavirus. Available at: https://www.nijz.si/sl/koronavirus-2019-ncov (Accessed 18. 11. 2021).
13. Olson S, Honeybul S, Rosenfeld JV. Considering Futility of Care Decisions in Neurosurgical Practice. World Neurosurg. 2021;156:120-124. doi: 10.1016/j.wneu.2021.09.078.
14. Jaswaney R, Davis A, Cadigan RJ, Waltz M, Brassfield ER, Forcier B, et al. Hospital Policies During COVID-19: An Analysis of Visitor Restrictions. J Public Health Manag Pract. 2022;28(1):E299-E306. doi: 10.1097/PHH.0000000000001320.
15. Nejadghaderi SA, Saghazadeh A, Rezaei N. Health Care Policies and COVID-19 Prevalence: Is There Any Association? Int J Health Serv. 2022;52(1):9-22. doi: 10.1177/0020731421993940.
16. Agyemang K, Rose A, Baig S, Al Salloum L, Osman AA, Steckler F, et al. Neurosurgery in octogenarians during the COVID-19 pandemic: Results from a tertiary care trauma centre. Interdiscip Neurosurg. 2021;26:101357. doi: 10.1016/j.inat.2021.101357.
17. Sander C, Dercks NV, Fehrenbach MK, Wende T, Stehr S, Winkler D, et al. Neurosurgical Care during the COVID-19 Pandemic in Central Germany: A Retrospective Single Center Study of the Second Wave. Int J Environ Res Public Health. 2021;18(22):12034. doi: 10.3390/ijerph182212034.
18. Ozoner B, Gungor A, Hasanov T, Toktas ZO, Kilic T. Neurosurgical Practice During Coronavirus Disease 2019 (COVID-19) Pandemic. World Neurosurg. 2020;140:198-207. doi: 10.1016/j.wneu.2020.05.195.
19. Panciani PP, Saraceno G, Zanin L, Renisi G, Signorini L, Fontanella MM. Letter: COVID-19 Infection Affects Surgical Outcome of Chronic Subdural Hematoma. Neurosurgery. 2020;87(2):E167-E171. doi: 10.1093/neuros/nyaa140.
20. O'Dwyer MJ, Owen HC, Torrance HD. The perioperative immune response. Curr Opin Crit Care. 2015;21(4):336-42. doi: 10.1097/MCC.0000000000000213.
21. Fontanella MM, De Maria L, Zanin L, Saraceno G, Terzi di Bergamo L, Servadei F, Chaurasia B, Olivi A, Vajkoczy P, Schaller K, Cappabianca P, Doglietto F. Neurosurgical Practice During the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Pandemic: A Worldwide Survey. World Neurosurg. 2020;139:e818-e826.
22. Berry G, Parsons A, Morgan M, Rickert J, Cho H. A review of methods to reduce the probability of the airborne spread of COVID-19 in ventilation systems and enclosed spaces. Environ Res. 2022;203:111765. doi: 10.1016/j.envres.2021.111765.
23. Malhotra N., Joshi M., Datta R., Bajwa S.J., Mehdiratta L. Indian Society of Anaesthesiologists Advisory and Position Statement regarding COVID-19. Indian J Anaesth. 2020;64:259-263.
24. Matava C.T., Kovatsis P.G., Summers J.L. Pediatric airway management in COVID-19 patients—consensus guidelines from the Society for Pediatric Anesthesia's pediatric difficult intubation collaborative and the Canadian Pediatric Anesthesia Society. Anesth Analg. 2020;131:61-73.