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MINIREVIEWS

Management of neurosurgical patients during coronavirus disease 2019 pandemics: The Ljubljana, Slovenia experience

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Abstract

The novel coronavirus disease 2019 (COVID-19) is an emerging disease, caused by severe acute respiratory syndrome coronavirus-2. It bears unique biological characteristics, clinical symptoms and imaging manifestations, therefore presenting an important and urgent threat to global health. As a result, a new public health crisis arose, threatening the world with the spread of the 2019 novel coronavirus. Despite the maximal worldwide public health responses aimed at containing the disease and delaying its spread, many countries have been confronted with a critical care crisis, and even more, countries will almost certainly follow. In Slovenia, the COVID-19 has struck the health system immensely and among all the specialities, neurosurgery has also been experiencing difficulties in the service, not only in regular, elective surgeries but especially during emergencies. The management of these neurosurgical patients has become more difficult than ever. We describe our protocol in the management of neurosurgical patients in the University Medical Centre Ljubljana, Slovenia and how neurosurgical pathology was tackled during the pandemics.

Key Words: Coronavirus disease 2019; Pandemic; neurosurgery; Patient management; Antivirus protocol; Ljubljana

Core Tip: The novel coronavirus disease 2019 (COVID-19) has become an important and urgent threat to global health. In Slovenia, the COVID-19 has struck the health system immensely and among all the specialities, neurosurgery has also been experiencing difficulties in the service, not only in regular, elective surgeries but especially during emergencies. In the article, we describe our protocol in the management of neurosurgical patients in the University Medical Centre Ljubljana, Slovenia.

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INTRODUCTION

The novel coronavirus disease 2019 (COVID-19) is an emerging disease, caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). It bears unique biological characteristics, clinical symptoms and imaging manifestations, therefore presenting an important and urgent threat to global health[1,2]. As a result, a new public health crisis arose, threatening the world with the spread of the 2019 novel coronavirus. Despite the maximal worldwide public health responses aimed at containing disease and delaying its spread, many countries have been confronted with a critical care crisis. The virus is supposed to have been originated from bats and was transmitted to humans through yet unknown intermediary animals in Wuhan, Hubei province, China in December 2019[3-6]. At the time of writing, in October 2021, the number of patients confirmed to have the disease has exceeded 230 million in more than 160 countries, and the number of people infected is probably much higher. More than 4.5 million people have died from COVID-19 infection. Despite public health responses aimed at containing the disease and delaying the spread, several countries have been confronted with a critical care crisis, and more countries will almost certainly follow[6-8].

The COVID-19 pandemics caused difficulties in every health system. European countries were almost equally affected and adjustments needed to be done to provide the necessary care for COVID-19 patients and normal functioning of the health system in parallel[9]. It is beyond the scope of this article to describe in detail the measures in every country. The European Union has issued recommendations for their member states on how to deal with the pandemics. Of course, there were differences among the European countries within their health policies[10,11]. In general, a numerous virus-protective practices at medical departments were introduced and protective actions were implemented to cope with the massive influx of COVID-19 patients and to preserve the regular medical services running normally. The hospitals needed to change their organization urgently. It was necessary to reallocate the medical staff, equipment and material, create management protocols, dedicate in-hospital routes and operating theatres for patients with COVID-19[9,12]. The regular management of patients in outpatient departments was altered into telemedicine-supported patient service and elective surgeries were postponed or stopped. Numerous adjustments were put into medical practice, such as rigorous control of both emergency and/or elective admissions, avoidance of inter-mixing of admitted and ambulatory patients and medical personnel, modifications and upgrading in treatment and operative practices, division of selected zones for treating COVID-19 patients and meticulous ward management practice. Additionally, some patients with COVID-19 had to undergo urgent surgery, while others became symptomatic within days of elective surgeries. For these, the treatment protocols were adjusted. The most affected countries were Italy, Portugal and Spain, followed by central European and Eastern European countries[9,10,13,14].

In neurosurgical care, there have been reports from various parts of the world including North America and Europe about the change in neurosurgical practice during the COVID-19 pandemic[10,13-15]. Especially neurosurgical patients demanding intensive treatment and long-term patients were affected due to a lack of resources. The supportive equipment, ventilators, intensive care unit beds, nursing and health personnel were redirected into the care of patients with COVID-19. The countries with better and more stable health systems suffered less impairment, which was evident already among the European countries. This was particularly evident during the peaks of infection waves. In the developing world with limited medical resources, dense and large populations, shortage of medical staff and already strained health infrastructure, these deficiencies were even more pronounced[9,11,16,17].

Slovenia is a central European country with a two million population. There are two neurosurgical centres, both located at university hospitals, one in the capital city, Ljubljana, and the second one in Maribor, which is the second-largest city in the country. The population of both cities encompasses 280000 and 95000, respectively. The Ljubljana neurosurgery department has 50 beds, the one in Maribor is half of its size. Both centres are concerned with all kinds of neurosurgical pathology. According to the regions involved, the neurosurgery department in Ljubljana covers approximately two-thirds of the country population and the neurosurgery department in Maribor is one-third of it. The first reported cases have emerged simultaneously with the infections that occurred in other central European countries and neighbouring countries bordering Slovenia. Due to the rapid progression of the virus spread, it was practically impossible to make considerable arrangements to tackle the pandemic and to adapt the health system to the new situation. 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 epidemic was declared a week after[18].

Compared to other European countries, the COVID-19 has struck our health system immensely[18]. Among all the specialities, neurosurgery has also been experiencing difficulties in the service, not only in regular, elective surgeries but also especially during emergencies. The management of these neurosurgical patients has therefore become more difficult than ever. As the majority of neurosurgical emergency patents need a swift and rapid consultation and quick medical intervention for the best possible treatment result, the fluency and speed of treatment are of vital importance[7,19,20]. The first factor here is the promptness of transportation. Both the time-lapse to neurosurgical care and the remoteness of transportation to the neurosurgical centre in Ljubljana with the availability proper neurosurgical care may considerably predict mortality and treatment results. In about 10% of patients, a decline in conciseness, measured by the Glasgow Coma Scale may be observed during the transport, when the transfer time to the health cantre longer than 4 h[19,20]. Those, who experience delays of more than 4 h before the surgery have a higher mortality rate compared to those, who present to the neurosurgical service directly. Therefore, one of the key elements causing a postponement of neurosurgical service is the remoteness of the neurosurgical centre[21]. The second problem is the potential COVID-19 infection[7,22]. The usual transit time to our centre varies, according to the type of transport, the helicopter of road transport, from 1 to 4 h, respectively. All emergency patients undergo virus testing initially and even on the best occasion, the rapid antigenic test needs 1 to 2 h to be completed, therefore prolonging the neurosurgical treatment. The polymerase chain reaction (PCR) test, with the higher sensitivity, needs even longer to be completed and cannot be used in the emergency setting. We use this test only for elective patients. Additional, the emergency patients are handled according to special anesthesiological and surgical procedures. The personal protection equipment, including special gloves, gowns, eye protection, face masks and eye shields were worn. The flow of staff into and from the operation room is minimised. Special care was taken for the equipment and postoperatively. All of these challenges may compromise the patient care and treatment outcome, with hospital organizations experiencing substantial expenses.

Besides the general measures to prevent virus spread on the state level, numerous adjustments at medical departments have been applied into medical practice and strict preventive actions were implemented. These included limitations of the regular outpatient management, increased use of telemedicine outpatient service and telephone consultations, the postponement of elective surgeries, adjustments and improvements in operative practice and treatment process, rigorous control of planned and urgent admissions, designation of high-risk zones for COVID-19 patients accommodation and surgery, special precautions on the medical departments and prevention of intermixing of cases and health care personnel. The purpose of this article was to describe the confrontation of COVID-19 difficulties for neurosurgery and how we have tackled these problems during the treatment of neurosurgical patients at the Ljubljana neurosurgery department.

THE MANAGEMENT PROTOCOL

In the pre-COVID-19 times, the elective neurosurgery patients at the University medical centre Ljubljana were admitted directly to the neurosurgery department and from emergency departments in case of urgent situations. They went through detailed clinical assessment, neuroimaging and routine medical examinations. The surgery of elective patients has been conducted in two elective operating theatres and one emergency operating room. This was reserved for urgent cases only. Before the pandemic, in the period from February 2019 to March 2020, a total of 1265 elective patients were operated on, 545 and 720 in every theatre. Altogether, there were 337 brain tumour patients operated on, 8 arteriovenous malformations (AVMs), 22 surgical aneurysm exclusions, 48 intracerebral haematomata (ICH) surgeries, 478 spinal surgeries, 62 hydrocephalus operations (excluding external ventricular drainages), 72 functional neurosurgical procedures and 316 various emergencies, including traumatic brain injury (Table 1).

During the epidemic, from March 2020 to April 2021, a total of 1233 patients were treated surgically. The patients worth the following pathology were included: 272 brain tumours, 6 AVMs, 24 aneurysms, 43 ICHs, 388 spinal surgeries, 51 hydrocephalus operations and 59 functional neurosurgical procedures. The rest included various types of vital pathology, again comprising severe brain trauma patients (Table 2). Since then we have arranged a special emergency neurosurgical operating room, which was dedicated to operating COVID-19 positive patients and was located strategically in the emergency area, very close to all the important premises for urgent patient's admission.

THE EARLY PHASE OF COVID-19 EPIDEMIC

The first step for neurosurgical patients, who needed neurosurgical treatment or assessment, was screening and evaluation. In the initial phase of the epidemic, there were not many COVID-19 positive patients. Therefore, general public measures were put in place (*e.g.* lockdown) and the admission for all urgent patients was limited to the emergency ward. These patients were managed immediately

Table 1 All neurosurgical cases operated on at our centre before the pandemic

	No of patents, theatre 1	No of patents, theatre 2
Neurosurgical pathology	673	560
Tumours	185	87
AVM	4	2
ICH	8	35
Aneurysm	20	4
Spinal	169	219
Hydrocephalus	19	32
Functional	19	40

AVM: Arteriovenous malformation; ICH: Intracerebral haematomata.

Table 2 All neurosurgical cases operated on during the months of the pandemic

	No of patents, theatre 1	No of patents, theatre 2
Neurosurgical pathology	545	720
Tumours	183	154
AVM	1	7
ICH	13	35
Aneurysm	16	6
Spinal	187	291
Hydrocephalus	30	32
Functional	19	40

AVM: Arteriovenous malformation; ICH: Intracerebral haematomata.

according to the underlying pathology and simultaneously tested for possible threat of COVID-19 infection with a nasopharyngeal swab for the rapid antigenic test (RAT) initially and then with a nasal swab for the rapid transcriptase (RT)-PCR test. The preoperative preparation, imaging, surgical and early postoperative care was performed with all necessary protective measures in positive patients and in those, in whom the nature of their illness required emergent surgical treatment. In COVID-19 negative patients, the management was ordinary. The emergency area was modified in such a way that a special separation area was established where urgent cases were tested an evaluated. All emergency, supportive and intensive care hardware was at hand. This area was isolated with no connection to other (safe) hospital areas. The initial rapid screening protocol for every patient included body temperature measurement and in awake patients, a detailed COVID-19 screening questionnaire was implemented. This was also included for patient relatives and attendants, especially in the instances of non-conscious patients, together with the strict use of protective actions, such as hand disinfection and face masks.

On the contrary, the elective patients and those requiring non-urgent transfer from other hospitals were directed to the neurosurgical ward and were temporarily accommodated in so-called transitional zones or specially established holding areas where RT-PCR was performed before surgery. They were tested for COVID-19 infection with the RT-PCR. After the test result became available, they were transferred to a regular ward to prevent possible COVID-19 infection. Also, all patents' escorts were requested to complete the questionnaire and respect strict protective measures at the time of admission.

THE LATE PHASE OF COVID-19 EPIDEMIC

In the later phase of the epidemic, when the number the cases has increased, the scheme described earlier changed. For isolation of neurosurgical patients managed at our centre at that time, all areas and treated patients were divided into three groups: red (danger zone, urgent patients), grey (transitional, waiting zone, elective patients) and green (safe zone, elective patents). In order of listing, the red one

was a high-risk zone, including the patients with confirmed COVID-19 infection and all vital emergencies brought to the general emergency admission department. In the emergency setting, these patients required an urgent, lifesaving neurosurgical intervention, regardless of the COVID-19 status and preventive and protective measures were taken here during their treatment. RAT was used for patients requiring immediate surgery on an emergency basis. The RT-PCR test was done during the operation, to accommodate these patients to suitable postoperative hospital areas. These urgent patients were operated on using full personal protective equipment. The second, grey group included all non-urgent and elective patients that were admitted to the neurosurgical department for regular treatment. These patients were those that were either vaccinated or tested in advance (before the admission) and were accommodated in grey zones to check their COVID-19 status with RT-PCR. This was the final check before relocating a patent to our green zone. When confirmed virus-negative, they were transferred to green zones. All transfer among these designated hospital and department zones was restricted also in terms of equipment, material and personnel. The green zone was the safe one, which included COVID-19 negative elective patients.

All emergency patients underwent this protocol, as well as admitted patients, who were classified based on the degree of treatment urgency. The life-threatened patients were directed for surgery at once, regardless of the COVID-19 status, unless proven otherwise. This group included a small number of patients with life-threatening neurosurgical emergencies that were already hospitalised on other hospital wards and were certainly COVID-19 negative when their health condition has deteriorated. In all hospitalised patients, the COVID-19 swabs were regularly taken every week as a control. The inclusion criteria for emergency surgery encompassed: (1) The paediatric patients and adults with clinical signs of elevated intracranial pressure, such as abscess, stroke, tumour, brain oedema, subdural or epidural hematoma, deteriorating hydrocephalus; (2) all traumatised patients needing surveillance or urgent surgery; (3) spinal compressive myelopathies (traumatic and non-traumatic), and (4) vascular emergencies: ruptured intracranial aneurysms, ruptured arteriovenous malformations, intracerebral haematomas. Special precautions were taken. Triage of the emergency patients was done according to the pathology and its complexity, the patient status, the obtainability of surgical instruments, the anaesthesiology team and the availability of postoperative accommodation (COVID-19/non-COVID-19 emergency rooms). The urgent patients were treated in concordance with the causal pathology, available resources and with all protective measures in the dedicated theatres. Postoperatively, they were treated in the designated red zone intensive care units until they were fit for discharge.

In those patients, where the contact to COVID-19 could not be confirmed, in COVID-19 negative patients, these were the elective ones, in semi-urgent patients and in patients with no acute respiratory signs and symptoms with a normal chest radiograph and negative RT-PCR COVID-19 tests, the risk of infection was low. They have been treated in a standard (pre-COVID-19) neurosurgical setting and postoperatively treated in green intensive care units (ICUs) or the green ward areas.

THE MANAGEMENT OF NEUROSURGICAL PATIENTS AND THE DISCHARGE CRITERIA

All patients with different neurosurgical emergencies, including neurotrauma and neurological diseases (all vital emergencies) that required prompt neurosurgical action, were admitted to the surgical general emergency department (Figure 1). After initial screening for COVID-19 with rapid antigen test (RAT) and then immediately with the RT-PCR test, the urgent patients were divided into two groups: (1) To those that could not wait; and (2) to those that could wait.

Those patients that could not wait were operated on immediately to save life or minimize the risk of neurological deterioration. These urgent patients were operated on in the COVID-19 operation theatre with full personal protective equipment. The RT-PCR test was done during surgery again to accommodate these patients after the operation to suitable postoperative hospital areas. If the test was positive, the patients were further treated in the red zones, which included the COVID-19 intensive care units and special areas on the neurosurgical ward. In case the patients have contacted COVID-19 during the hospital stay, they transferred to the same red areas or discharged home, when in appropriate condition. Those patients that were in contact with COVID-19 and were not confirmed positive, were transferred and treated in the grey areas, which included intensive care therapies and normal ward care. They were tested with the RT-PCR every day during the treatment and when negative, transferred to green areas.

The patients that could wait were addressed according to the COVID-19 RT-PCR test. When negative, they were treated in the green areas and when positive, they were transferred to the red areas.

The elective patients were involved in a separate leg and they were completely separated from the emergency patients. They were first admitted into grey areas at the neurosurgical department and waited for the results of the RT-PCR test. When positive, they were discharged home. When negative, they were treated in the green areas, including intensive care units and normal ward facilities.

All patients were regularly tested with RT-PCR tests when treated on the ward and in the ICU. In green zones, the tests were taken 24 h apart, in red areas they were tested every 72 h. Grey res were transitional places, where the RT-PCR tests were undertaken daily. Grey res were transitional places.

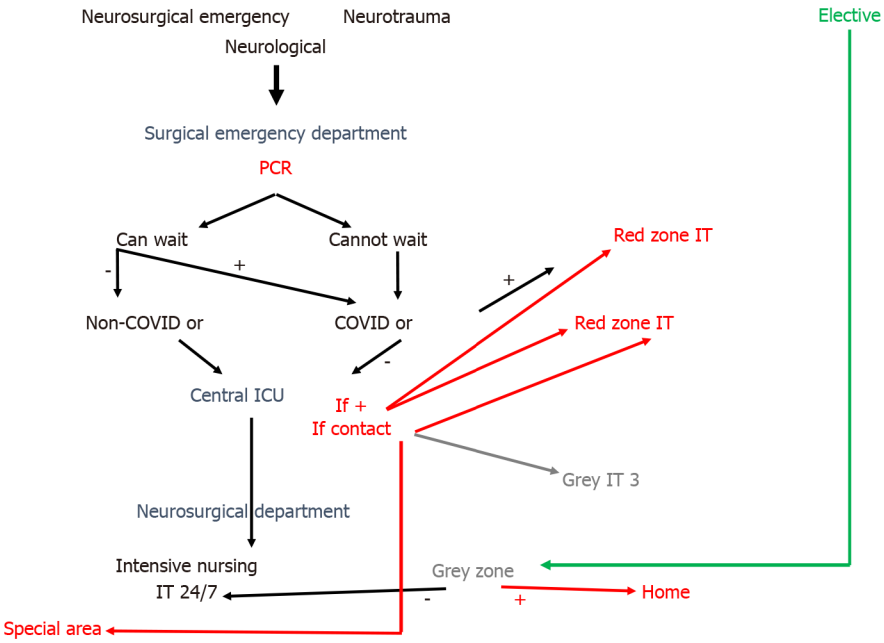

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Figure 1 A schematic representation of the flow of neurosurgical patients at the University medical centre Ljubljana. Patients with different neurosurgical emergencies were admitted to the surgical general emergency department. After initial screening for coronavirus disease 2019 (COVID-19) with rapid antigen test and the rapid transcriptase polymerase chain reaction (RT-PCR) test, the urgent patients were divided into two groups: (1) to those that could not wait; and (2) to those that could wait. (1) Those patients that could not wait were operated on immediately in the COVID-19 operation theatre. The RT-PCR test was done during surgery again. If positive, the patients were further treated in the red zones, including the COVID-19 intensive care units and special ward areas. In case the patients have contacted COVID-19 during the hospital stay, they were transferred to the red areas or discharged home. The patients in contact with COVID-19 and not positive, were transferred to grey areas; and (2) The patients that could wait were addressed according to the COVID-19 RT-PCR test. When negative, they were treated in the green areas and when positive, they were transferred to the red areas. The elective patients were first admitted into grey areas in the neurosurgical department and waited for the RT-PCR test. When positive, they were discharged home. When negative, they were treated in the green areas. PCR: Polymerase chain reaction; COVID: Coronavirus disease; ICU: Intensive care unit.

When negative, the patients were transferred to green areas. When positive, they were treated further in red areas.

After the neurosurgical treatment, the patients were discharged from the ward as soon as possible to generate new capacities. Most of them were discharged home, some also to the rehabilitation facilities, depending on their health condition. The length of hospital stay depended on the type of pathology, recovery, flow and general condition of the patient. For example, when no complications occurred, patients having had microdiscectomy were discharged home after two to three days, spinal fixation required four days of hospitalisation, the operations of brain tumours and vascular pathology (unruptured aneurysms, AVMs) required five to seven days of hospitalisation. There were more difficulties encountered in long term treatment, including trauma patients, infections, haemorrhages, those with complications and concomitant diseases, since these patients were unable to be discharged from the hospital early. Longer recovery was expected here and they were later transferred to special rehabilitation and nursing institutions. The treatment here varied, from several weeks to months.

From the COVID-19 point of view, the discharge criteria from the isolation (suspending transmission-based precautions) were the following: (1) Ten days after the beginning of symptom, plus no less than three extra days without symptoms (with no elevated body temperature and respiratory tract symptoms) for symptomatic patients; and (2) ten days after a positive COVID-19 test in patients, who had no symptoms. To confirm the clearance of virus, and thus allow discharge from isolation, required a patient to be clinically well and to have two negative RT-PCR results on sequential samples, which were taken 24 h apart.

A special regimen was held at the outpatient clinic. Every patient acquired a slot for consultation. Only RAT-tested and COVID-19 negative patents were admitted for con consultations and this certificate was checked at the entrance. Upon arrival to the neurosurgical outpatient clinic, every patient filled in the questionnaire regarding health conditions and possible COVID-19 symptoms and exposure. The separation of seating was in effect in the waiting room and all areas were ventilated frequently. Preferably and when possible, the windows were opened all the time when the patients were on the premises. Face shields and masks were worn by the staff and when possible, the e-consultations and the telephone- consultations were used.

PERSONAL PROTECTIVE MEASURES

In the emergency area, all patients were evaluated by an anesthesiologist, traumatologist and neurosurgeon with the attending nursing staff. All personnel in contact with the patient respected protective measures and wore N95 or FFP3 masks and face shields in addition to hand gloves and protective attire. Auxiliary staff were required to wear personal protective equipment. All neurosurgical staff wore N95 or FFP3 masks and face shields and ordinary operating room gown and clothing. The anaesthesiology and support personnel in the operating theatre used the same safety measures. During the intubation, only the anesthesiologist and the assistant remained in the operating theatre, all other staff was waiting outside until the procedure was completed. Once the patient was connected to the respirator, they entered the theatre. When performing craniotomy, ski glasses or transparent face shields have been used and bone drilling with abundant irrigation. When possible, electrosurgical knives were combined with suction devices to remove the contaminated smoke. The mobility was limited to one entrance and exit from the operating theatre, the floor was disinfected with alcohol and chlorhexidine solution and a disinfectant-soaked mat was kept there to limit the potential spread of the virus on the footwear. The auxiliary staff in the outer area wore a face shield, a 3-ply surgical mask and protective gear. The central unit-governed air conditioning was closed for the time of the operation and later, the theatre was thoroughly disinfected. For COVD-19 positive patients in the ICU or on the ward, the same precautions were taken. The RT-PCR was done twice weekly regularly or according to the needs during the recovery period. To make the accommodation for new admissions, the patients were directed home as soon as possible after the operation.

In grey areas, the protective equipment included N95 or FFP3 masks, protective face shields or protective glasses and single-use attire. At the entrance, the dressing-up and disinfection were mandatory. In green areas, the service was standard and the protective measures included 3-ply surgical masks and protective glasses. The nasal swabs for RT-PCR were taken twice weekly for control.

OUR EXPERIENCE WITH TELEMEDICINE

The advances of information-communication technology in recent years have made medical consultations easier, among other advantages. During the COVID-19 epidemics, the neurosurgical consultations *via* the telemedicine system showed to be a priceless tool for care and management of patients, as observed by the treating neurosurgeons in our medical centre[23-25]. In the national hospital network, we are using the telemedical network named Telestroke. In the pre-epidemic period, this system was used principally for neurological emergencies and urgent stroke management. To control the influx of patients to our medical centre because of the lack of available beds during the epidemic, we aimed to transfer only those patients that undoubtedly needed neurosurgical service. Here, the Telestroke proved to be extremely valuable. It has helped the anaesthesiologist and neurosurgical team to prepare for the COVID-19 screening, surgery, accommodation procedure, the postoperative treatment in the ICU and the ward. During the usage of the Telestroke system in the University medical centre Ljubljana, patients with various pathologies have been treated. These included brain trauma (epidural and subdural haematomas, contusions, cranial fractures, and soft tissue injuries), cerebral vascular diseases (aneurysms, arteriovenous malformations, ischemic and haemorrhagic strokes), cerebral oedema of numerous aetiologies and primary and secondary brain tumours where oedema or bleeding happened and the patients' neurological status worsened as a result of rapid rise of intracranial pressure. During the epidemic, the Telestroke proved to be a vital mode for conveying the medical information, to communicate and connect between the peripheral hospitals and our referral centre, limiting the load of patients in the tertiary centre.

DISCUSSION

During the period of the epidemic, it was necessary to organise and adapt the neurosurgical practice according to new rules. Despite the difficulties the virus spread has caused to the health system, it was necessary to keep in mind that regular medicine needs to work continuously and in parallel with the treatment of COVID-19 patients[19,26,27]. The flow of patients to the health institutions is not reduced during the epidemic, it is rather increased, and the current virus pathology is intermingled with the everyday health problems, which also need to be addressed adequately and professionally. This is particularly important for neurosurgery where the emergencies need to be handled quickly in order not to cause additional damage to the nervous system[28,29].

Our neurosurgical department is the largest in Slovenia and deals with all kinds of neurosurgical pathology. Due to the constant inflow of patients, it was necessary to limit the pathology according to the treatment priority. This means, that we have implemented a triage system on the level of the outpatient clinic, to minimise patient admission and to adapt to the new situation. It should be noted, that all the emergencies were managed instantly and with no delay.

All patients with COVID-19, who underwent surgery, were transferred into special COVID-19 treatment facilities, which are available at our medical centre and offer all the necessary treatment, including intensive care. They were regularly visited by neurosurgical consultants and their treatment was conducted together with the treating specialists at the COVID-19 departments. With a meticulous screening policy and selection of cases, the safety of admitted patients and those treated at our department has increased during the months of the epidemic. We have recorded only two COVID-19 intrusion incidents. These patients were then discharged home since they were discovered positive before the planned surgery. One patient was confirmed positive after the operation and was transferred to the COVID-19 treatment facility.

We did not record an important decline of the number of operated patients. We are aware that the number of patients included in the study was relatively low and that this was a limitation to our study. However, since we are a medium volume centre, it is impossible to obtain higher numbers in the examined periods, namely in the study periods from February 2019 to March 2020 (the pre-COVID-19 period) and from March 2020 to April 2021 (the COVID-19 period). The whole population of Slovenia is about two million and our centre covers three-quarters of the country. The inflow of patents was constant during the last years and it was the same also during the epidemic period. Of course, the regimen of medical examinations, follow-ups and admissions was adapted according to the situation during the pandemics. We are aware that the numbers of patients in the study cannot be compared to other high volume and high-frequency centres across Europe and the world. The numbers we obtained were used for illustrative purposes and to conclude from our practice, that it is possible with an accurate protocol and strict anti-COVID-19 measures to enable the neurosurgical service to run even in challenging times. An exact screening and a strict triage system enabled us to keep up with the inflow of patients. The triage system classified the patients according to the pathology and the necessity of action. They were operated on when needed and treated according to individual requirements. The time saving measures and procedures, such as non-urgent spinal operations and some special procedures such as awake surgery were put aside whenever possible and conservative treatment, at least for some period, was advised[30]. Elective surgeries, including tumour, vascular, hydrocephalus and semi-urgent elective spinal operations were running almost normally. The waiting time for these surgeries did not change during the epidemics.

As mentioned, special precautions were implemented for patients with urgent neurosurgical that were COVID-19 positive. These patients were operated on immediately in the COVID-19 operation theatre. The intubation was done according to a quick protocol by the anaesthesiologist and the nurse assistant. At that time, no other staff were present in the operation theatre. After intubation, the surgical staff approached and started with the procedure. Personal protective equipment was worn all the time and the protective measures were respected. The equipment and material in the operating theatre were kept to a minimum. During the surgery, the RT-PCR test was done to help with the postoperative patient accommodation arrangement. When confirmed positive, the patients were further treated in the red zones, which encompassed the COVID-19 ICUs and special areas on the neurosurgical ward. Sometimes, the patients were caught positive while hospitalised. The RT-PCR tests were done here every two days. In these instances, the patients were transferred to red areas and treated there according to their condition. When ICU was needed, the patients were transferred there. In more stable health conditions, they were treated in the red areas on the neurosurgical ward. Alternately, when their condition allowed, they were discharged home.

It is very important to manage patients in the operation theatres carefully and correctly, to limit the potential spread of the virus[29-31]. The separation of hospital areas into zones and rapid antigen testing are practical measures that have proven very successful. All medical personnel need to respect protective measures, such as proper face masks, face shields, appropriate gloves and attire. A good alternative to FFP3 or N95 mask are half- or full-face respirators. Powered air-purifying respirators may be utilised when accessible. They have shown a good effectiveness and improved protection[32-34]. However, we did not use these during the operations. They were only used in the COVID-19 ICUs. When surgery is needed in these situations, the operating theaters with negative pressure are ideal[22, 35]. However, not all centres have such facilities, including ours. Special measures in anaesthesiology procedures included emptying the operation theatre during intubation and rapid sequence intubation, which prevented aerosol spread. The high-risk anaesthetic procedures involved intubation and extubation, cardiopulmonary resuscitation, ventilation through face mask, the cleaning of respiratory secretions and providing high-flow nasal oxygen[36,37]. Procedures that were considered low-risk included external ventricular drainage and placement of the lumbar drainage. Only the essential gear and equipment was stored in the operating theatre and when possible, the disposable one was used in confirmed cases. Extubation was done on the operating table since this minimises the risk for cross-infection and ample time should be provided for proper operating theatre disinfection. In addition to regular precautions, such as minimal drilling and abundant irrigation, we tried to avoid the trans-nasal procedures (for hypophyseal tumours) unless in urgent indications (apoplexy, loss of vision). Additionally, a clear delineation of roles, disinfection and aeration plan and, and cross monitoring of all staff members for potential contamination with reduction of the number of persons in the theatre at a time is advantageous[22,32,38].

CONCLUSION

The COVID-19 epidemic is far from over and the hospital system in Slovenian is still struggling under its pressure. Despite the difficulties, we are trying to assure that the medical services run as normal as possible, not only for neurosurgical patients but also for those that need all other clinical specialities. By following the strict testing and triage system, the segregation of patients and by respecting the protective producers for the patients and the staff, we managed to provide uninterrupted neurosurgical care during the COVID-19 epidemic. Despite this fact, we will need new and enhanced strategies to deal with this epidemic in the future without compromising the normal health system, particularly for lifesaving procedures in critical specialities, as is neurosurgery.

FOOTNOTES

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