CORRESPONDENCE Letter: The Risk of COVID-19 Infection During Neurosurgical Procedures: A Review of Severe Acute Respiratory Distress Syndrome Coronavirus 2 (SARS-CoV-2) Modes of Tr...

Article *in* Neurosurgery · April 2020

DOI: 10.1093/neuros/nyaa157/5825348

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Letter: The Risk of COVID-19 Infection During Neurosurgical Procedures: A Review of Severe Acute Respiratory Distress Syndrome Coronavirus 2 (SARS-CoV-2) Modes of Transmission and Proposed Neurosurgery-Specific Measures for Mitigation

To the Editor:

The novel coronavirus disease of 2019 (COVID-19) is a disease caused by the severe acute respiratory distress syndrome coronavirus 2 (SARS-CoV-2). It was first reported in December 2019 as a series of cases of pneumonia with an unknown etiology clustered around a food market in Wuhan City, China.[1] The infection spread quickly and was declared a pandemic by the World Health Organization (WHO) on March 11, 2019.[2] By March 30, more than 782 365 confirmed cases were reported and a third of the world population were living in confinement to try to contain the virus.[3] While the disease itself is often mild, approximately 11% of cases require acute medical care, and this cohort quickly overwhelmed healthcare systems around the world.[4] In anticipation of such a demand, hospitals in many countries quickly stopped all nonurgent visits, procedures, and surgeries, freeing up beds, equipment, and workforce.[5]

While neurosurgeons are not on the frontline of COVID-19 management and treatment, they commonly care for critically ill patients who will continue to present with subarachnoid hemorrhages, subdural hematomas, brain tumors, traumatic brain injuries, spinal cord injuries, and compressive myelopathies while the pandemic occurs. While public health measures such as quarantine and social distancing are proving effective at slowing the spread,[6,7] surgeons remain in direct contact with their patients throughout their operations. Protecting the surgical team from contracting COVID-19 is of utmost importance as they are both a potential vector for patient contamination and a scarce resource that cannot be easily replaced.

The goal of this paper is to briefly review how SARS-CoV-2 is transmitted and propose measures that could be implemented to minimize the risk of contaminating the operating room (OR) personnel during the most common neurosurgical procedures. Methods and ethical considerations are discussed in the **Supplemental Digital Content**.

SARS-COV-2 TRANSMISSION

Sites of Entry

Phylogenetic analysis revealed that the SARS-CoV-2 virus probably evolved from the bat SARS-like CoV (bat-SL-CoVZC45, MG772933.1) virus.[1,8,9] It falls into the genus β-coronavirus, which includes SARS-CoV (80% sequence homology) and Middle East respiratory syndrome coronavirus (MERS-CoV), both responsible for previous outbreaks in 2003 and 2012, respectively. Human-to-human transmission was well documented early on and contributed to the rapid spread of the disease.[9,10] The virus has been shown to exploit the angiotensin-converting enzyme 2 (ACE2) as a receptor for cell entry, as was the case for SARS-CoV, but unlike MERS-CoV.[8,11-13] ACE2 is expressed in the human airway epithelium, lung parenchyma, vascular endothelium, kidney cells, small intestine cells, and, to a lesser extent, central nervous system (CNS) cells.[14,15] This pattern of expression therefore supports the respiratory and gastrointestinal tracts as the primary sites of entry.

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Biodistribution

Once infected, individuals can show varying tissue responses and virus biodistribution. In a study of 1070 specimens from 205 inpatients with proven COVID-19, SARS-CoV-2 ribonucleic acid (RNA) could be detected in 93% of bronchoalveolar lavage fluid specimens, 72% of sputum, 63% of nasal swabs, 46% of fibrobronchoscope brush biopsies, 32% of pharyngeal swabs, 29% of feces, and 1% of blood samples.[16] Another study using a different methodology and timing of specimen collection showed viral RNA could be detected in blood samples (40% of patients) and anal swabs (27% of patients) even after the oral swabs became negative.[17] Three other groups reported a rate of positive blood detection of 10% to 17% of patients, including in nonfebrile and asymptomatic carriers.[9,18,19] In some studies, the detection of viral RNA in blood was a strong indicator of future clinical severity.[18] So far, the virus has not been detected in urine samples.[16] Together, these results suggest there might be a shift in virus distribution from the respiratory tract early on to the gastrointestinal tract later on, with viremia possibly persisting for some time after the resolution of the respiratory tract infection or in asymptomatic carriers.[17] This has significant implications for COVID-19 diagnosis, as the sensitivity of tests will be influenced by both the tissue sampled and the timing of the sampling.

A concerning finding for neurosurgeons is the hypothesis that SARS-CoV-2 might have tropism for the CNS.[20,21] There is accumulating anecdotal evidence that anosmia and associated dysgeusia could be symptoms of COVID-19 even in the absence of other respiratory manifestations. Such an observation was also made in a SARS patient,[22] and transgenic mice models have demonstrated that SARS-CoV could infect the olfactory bulb neurons and reach the CNS through trans-synaptic spread.[23] There is so far only one published report of SARS-CoV-2 detection in the cerebrospinal fluid (CSF) of a human patient[24] and no study demonstrating complete virions in either the CSF or the CNS. However, this possibility should be kept in mind and has been proposed by some authors to explain the lack of central breathing drive observed in many intubated severe COVID-19 cases.[21]

Shedding and Transmission

Detection of viral RNA by polymerase chain reaction (PCR), however, does not imply the existence of intact, infectious viral particles. To be transmitted, the complete and assembled virus needs to be shed by the contaminated host and transported to an entry tissue in a new potential host. So far, the presence of live virus shedding was confirmed from human airway epithelial cells[1] and feces specimens, occurring even in patients who did not have diarrhea.[16] There is no evidence yet that the fully assembled virus can be detected in the blood, although a controversial study during the 2003 SARS epidemic suggested that blood transmission of SARS-CoV occurred in Hong Kong[25] and many blood transfusion agencies are refusing blood donations from COVID-19 patients.[26] Once outside of the contaminated host, SARS-CoV-2 virions have a half-life of 1.1 h in aerosols, 3.5 h on cardboard, 5.6 h on stainless steel, and 6.8 h on plastic.[27] These observations suggest SARS-CoV-2 infection can occur via direct or indirect transmission. Direct transmission can occur through contact (eg, kissing an infected individual) or droplets (eg, inhaling virion-containing aerosols immediately after an infected patient coughed, sneezed, or talked). Indirect transmission can occur through fomites (such as touching a contaminated surface and then touching one's mouth or nose) or through airborne transmission (such as aerosolization of virions during medical procedures). The current consensus is that SARS-CoV-2 is transmitted primarily through the respiratory and possibly fecal-oral routes.[1,28] There is no evidence so far for blood transmission[26] and there are conflicting reports on vertical transmission from a pregnant woman to her fetus.[29,30]

The magnitude of the pandemic highlights how infectious SARS-CoV-2 is. Early estimates of the basic reproduction number (R_0) range from 2.2 to 6.49 people infected by every contagious individual, compared to 1.28 for the common flu and 1.46 for the H1N1 2009 pandemic.[31,32] This might be explained by the existence of contagious asymptomatic carriers,[33] which might represent 17.9% of infected individuals, including a high proportion of children.[34]

SARS-CoV-2 Virus and Immunity Testing

The current gold standard for COVID-19 diagnosis is through the detection of SARS-CoV-2 RNA using reverse transcription polymerase chain reaction (RT-PCR) on respiratory material (typically a nasopharyngeal and/or oropharyngeal swab).[35] The specific gene target, primers, and probes used are highly variable across countries, as are the specimen analyzed (eg, upper respiratory, lower respiratory, blood, stools) and the timing of specimen collection. As such, no reliable data are currently available on the sensitivity and specificity of COVID-19 testing. While a South Korean study of 10 cases suggested a false-negative rate of 20% for RT-PCR,[36] larger studies will be required to confirm this finding. Meanwhile, new point-of-care tests are also in development and will use different technologies, such as immunoassays and clustered regularly interspaced short palindromic repeats (CRISPR), which will again require validation.[37] There is no test available yet to confirm the immune status against SARS-CoV-2,[37] although combined IgG-IgM assays can now assess exposure.[38]

GENERAL MEASURES TO PREVENT PERIOPERATIVE NOSOCOMIAL SPREAD

In China, 3.8% (1716 of 44 672) COVID-19 cases occurred in healthcare workers, with 14.5% of these (254) considered severe and 5 leading to death.[39] Later reports suggested the first nosocomial spreading event occurred during a pituitary surgery in which 14 people present in the case were infected.[40] Infected personnel can act as vectors for disease propagation before becoming symptomatic, quarantined, and unable to deliver care.

General measures are being implemented in most hospitals to prevent perioperative nosocomial spread of SARS-CoV-2. One of the most detailed and impressive reports of such measures comes from a large tertiary hospital in Singapore.[5] This group applied the "hierarchy of controls" framework[41] to the COVID-19 pandemic to reorganize their OR environment and workflows, as detailed in Table 1. The framework suggests that the most effective way to protect from a hazard is elimination (physically remove the hazard). If impossible, fallback options are substitution (replacing the hazard), followed by engineering controls (isolating people from the hazard), followed by administrative controls (changing the way people work), and, lastly, protecting workers using personal protective equipment (PPE). Each institution will have its own protocol and it is critical that all personnel be familiar with the local procedures.

NEUROSURGERY-SPECIFIC RISKS AND MITIGATION STRATEGIES

In neurosurgical practice, we anticipate 3 settings where the risk of SARS-CoV-2 transmission in the OR might be the highest:

(1) during endotracheal intubation and extubation;
(2) during surgeries exposing the respiratory or digestive tracts;
(3) during the use of instruments producing aerosolization of virion-contaminated tissues.

Understanding these high-risk settings provides an opportunity to optimize our procedures to minimize nosocomial transmission.

Risk Related to Endotracheal Intubation and Extubation

Airway manipulation represents a significant risk of respiratory infection transmission among healthcare workers. In a 2012 systematic review, endotracheal intubation had a hazard ratio (HR) of 6.6 (95% CI 4.1-10.6) for respiratory virus transmission, over tracheotomy (HR = 4.2, 95% CI 1.5-11.5), noninvasive ventilation (HR = 3.1, 95% CI 1.4-6.8), and manual ventilation before intubation (HR = 2.8, 95% CI 1.3-6.4).[42] Guidelines for the management of airway in COVID-19 patients have just been

TABLE 1. General Measures to Prevent Perioperative Nosocomial Spread as Implemented in Singapore[5]

• Hospital measures related to surgery and anesthesia: ○ Reduce elective activities to increase capacity and accommodate infection prevention measures ○Screening of patients, visitors, and staff for symptoms or travel history ○ Setting up efficient communication channels with staff (COVID-19 website, helpline for anxiety and burnout)
• OR management: ○ Reserve a specific OR area for COVID-19: ■ Independent, negative pressure ventilation ■ Physically isolated from the main OR ■ Control traffic by locking all but the scrub room door during surgery ○ Assign an anesthetic team exclusively for COVID-19 patients ○ Design and teach new workflows for COVID-19 patients
• Anesthesia staff training and management: ○ Formal N95 fitting sessions ○ Formal training sessions on PPE use ○ Segregation of staff between hospitals to minimize the risk of nosocomial spread from one hospital to the other ○ Attendance tracking on all face-to-face meeting to facilitate contact tracing in the event of an outbreak ○ Postponement of all nonurgent preoperative visits ○ Pregnant or immunocompromised staff did not care for COVID-19 patients
• Mandatory use of PPE: ○ When caring for low-risk patients (asymptomatic and no history of travel or contact with COVID-19 patient): surgical masks and droplet precautions ○ When caring for high-risk patients: N95 masks, eye protection, gown, and gloves ○ When caring for COVID-19 patients: N95 masks, eye protection, gown, and double gloves ○ When performing aerosol-generating procedures on COVID-19 patients: powered air-purifying respirator
• Specific measures when caring for COVID-19 patients ○ Patients should wear a surgical mask during transport ○ Patients are transported using a designated route minimizing the risk of encounter ○ Keep the COVID-19 OR as empty as possible and only bring equipment and drugs as needed ○ Use single-use equipment as much as possible ○ Do not bring paper charts into the COVID-19 OR ○ Cover all monitors, computers, and machines in plastic wrap ○ Perform the patient review, induction, and recovery within the OR to limit contamination to a single room ○ Limit the number of staff in the OR ○ Limit the movement of staff in and out of the OR
• OR decontamination after COVID-19 surgery ○ Discard the anesthetic breathing circuit and soda lime canister ○ Clean all surfaces with quaternary ammonium chloride disinfectant wipes ○ Clean OR with sodium hypochlorite 1000 ppm ○ Treat OR with hydrogen peroxide vaporization or ultraviolet C irradiation ○ All staff to shower and change into new scrubs after each COVID-19 case
• Perform a series of simulations and walkthroughs of the COVID-19 workflow

published[43,44] and should help anesthesiologists mitigate this risk as much as possible, especially given the higher contagiousness of COVID-19.[32]

What neurosurgeons can do to help, however, is to reappraise the necessity for general anesthesia (GA) and endotracheal intubation in their patients. Many procedures routinely performed under GA in most centers can easily and safely be accomplished under conscious sedation, local anesthesia, and/or spinal anesthesia with the patient wearing a face mask to limit aerosolization in the OR. These include external ventricular drain (EVD) placement, chronic subdural hematoma (CSDH) evacuation,[45] carotid endarterectomy,[46] and lumbar discectomy or laminectomy,[47,48] among others. If GA is absolutely required, all unnecessary personnel (including most neurosurgeons) should not be in the room while intubation and extubation are performed. Awake fiberoptic intubation should be avoided if possible, as should any procedure that might induce coughing.[49]

Risk Related to Respiratory and Digestive Tract Exposure

Given the biodistribution of SARS-CoV-2, procedures involving the respiratory tract generate the highest risk of nosocomial transmission. Anecdotal, unpublished reports from China suggest that ENT surgeons might be the most affected of all healthcare workers. For neurosurgeons, this risk arises during trans-sphenoidal approaches, transmastoid approaches, transoral approaches, percutaneous trigeminal rhizotomies as well as craniotomies involving the frontal sinuses, such as bicoronal, bifrontal craniotomies or frontal skull fracture repair. In the setting of a local outbreak or in COVID-19 positive patients, surgeons should try to delay these procedures or use alternative approaches, wherever possible. Most trans-sphenoidal surgeries, for instance, are performed for benign lesions that can usually be delayed until after the pandemic, or at least after the patient's COVID-19 status is negative. For procedures that cannot be postponed (eg, pituitary apoplexy, craniopharyngioma with obstructive hydrocephalus), serious consideration should be given to a transcranial approach (eg, pterional) or an alternative strategy (eg, a cystic craniopharyngioma could be drained through stereotactic implantation of an Omaya reservoir and treated using intracavitary therapies rather than trans-sphenoidal resection). The same applies for translabyrinthine approaches for vestibular schwannomas, which can usually be substituted for a retrosigmoid craniotomy. Whenever performing a craniotomy, extra care should be placed in avoiding the frontal sinuses or mastoid air cells, which can be facilitated by the use of neuronavigation. In frontal sinus fractures, conservative treatment or lumbar drainage could be attempted until COVID-19 status is negative. Patients with trigeminal neuralgia could be offered radiosurgery over rhizotomy, if pain control cannot be achieved pharmacologically. For spine tumors or trauma, dorsal approaches should be favored over transthoracic surgeries to minimize the risk to the lung parenchyma.

When exposure to the respiratory tract is unavoidable, patient decolonization could be attempted in COVID-19-positive patients. Along with standard chlorhexidine skin preparation, intranasal povidone iodine preparation (especially in endonasal approaches) and chlorhexidine or hydrogen peroxide mouth rinse have been used,[50] although the efficacy of this approach remains unproven.

The involvement of the gastrointestinal tract can also theoretically increase the risk of SARS-CoV-2 infection if breached. Although a rare instance in neurosurgery, this could happen if the esophagus is lacerated during an anterior approach to the cervical spine, if an anterior instrumentation is eroded through the mucosa, or if the bowel is perforated during ventriculoperitoneal (VP) shunt placement. Surgeons should be careful, as always, to avoid these complications and should escalate the PPE requirements and OR decontamination protocol if they happen during a case. For VP shunts, dissection under direct vision would be advisable as opposed to blind trocar insertion of the abdominal catheter. Consideration should also be given to endoscopic third ventriculostomy (ETV) when deemed equally effective.

Risk Related to Aerosol-Generating Instruments on Virion-Containing Tissues

A most prevalent, yet *highly* theoretical risk faced by neurosurgeons is an airborne transmission of the virus resulting from the use of aerosol-generating instruments. These include all powered drills,[51-53] electrocautery,[51,54] lasers,[55] ultrasonic aspirators[56] as well as insufflators used for pneumoperitoneum maintenance during laparoscopic surgery.[57] To be infectious, aerosolized particles need to contain virions. This is definitely the case in the respiratory and digestive tracts. Conclusive studies are lacking for CSF, CNS tissue, and bone, while the clinical significance of aerosolized blood remains uncertain. As discussed above, SARS-CoV-2 RNA can be detected in the blood of 10% to 40% of COVID-19 patients.[9,17-19] While RNA detection does not imply the presence of complete viral particles, our understanding in the case of SARS-CoV-2 is still limited.

It would therefore appear prudent to limit the use of aerosol-generating instruments if surgically possible, (1) in the setting of COVID-19-positive cases, (2) if a nosocomial spread of uncertain origin is occurring locally, or (3) if the surgical approach requires exposure or proximity to the sinuses or mastoid. In any of these cases, rongeurs and curettes should be favored over drilling with a burr. Burr holes can be performed using a Hudson brace or a twist drill rather than a perforator, especially for EVD placement or CSDH, where a single hole may be sufficient.[58-60] In trans-sphenoidal surgery, rongeurs and chisels can replace high-speed drilling. In the setting of spinal decompression and stabilization, bony removal can usually be achieved with various rongeurs, and manual, tactile pedicle probes are suggested to facilitate the placement of pedicle screws. In any case where drilling is used, the drill could be used at lower speeds and should be stopped when irrigating. Large suctions should be used to aspirate as much particulate matter as possible and isolate the drilling area using a transparent adhesive film (eg, Opsite™; Smith & Nephew) "tent" or gauzes could be attempted. In spine surgery, the use of navigation as well as minimally invasive techniques such as endoscopic procedures and percutaneous screws should be considered to lower the amount of drilling required. Smoke from electrocautery should be immediately aspirated. The use of lasers and ultrasonic aspirators should be limited. Finally, VP shunt placement could be performed open rather than laparoscopically to avoid the aerosolization created by the carbon dioxide insufflator.[57] Lastly, aerosol-generating instruments should be manipulated by proficient users rather than learners. Some of these intraoperative precautions (including reducing the speed of drilling) have been successfully taken by a group of neurosurgeons in Wuhan city, where most of the focus, however, was on reducing bleeding and shortening the time of surgeries.[61]

PREOPERATIVE SARS-COV-2 TESTING

When surgery is required and authorized, but not urgent, systematic SARS-CoV-2 testing of low-risk and asymptomatic patients should be considered based on the local epidemiology and availability of testing resources. Given that 17.9% of infected individuals might by asymptomatic carriers,[34] this measure has the potential to significantly reduce nosocomial spread while preserving PPE supply in the context of global shortages[62] (Table 1). This would be achieved by delaying procedures after infected patients are cured and limiting the use of more stringent

TABLE 2. General Organizational Measures of Particular Importance to Neurosurgery During the COVID-19 Pandemic

- Operate on as few patients as possible:
  - Only perform surgeries that cannot be delayed
  - When an alternative to surgery exists and is equally valid, favor the alternative
  - If the healthcare system becomes overwhelmed, only offer surgery to patients who have a reasonable prognosis
- Involve as few people as possible in the surgical procedures:
  - Keep the number of individuals in the OR to the minimum required for safe completion of the surgery
  - Do not involve observers, students, and even residents who do not have an indispensable role
  - Minimize personnel turnover by extending shifts and minimizing breaks
  - Segregate surgeons in specific hospitals to minimize nosocomial transmission from one hospital to another
  - If possible, assign all COVID-19 patients to a single team that will minimize contacts with other surgeons
  - Once immune status testing becomes available and reliable, consider assigning contamination-prone tasks and COVID-19 patients to staff with proven immunity.
- Depending on local epidemiology and resources, consider testing all surgical patients for SARS-CoV-2 or treating all patients (even asymptomatic) as potentially infected

PPE in negative cases. The caveat, however, is that until COVID-19 tests are standardized and their sensitivity and specificity known at the local level, a negative test might provide a false sense of security and paradoxically increase nosocomial transmission. Some authors have recommended repeating the COVID-19 PCR assay due to this relatively high possibility of false negatives.[63] Additionally, patients with a high clinical suspicion of COVID-19 infection with a negative test should be considered as infected. Patients should also be asked to take additional precautions (ie, self-quarantine) in the period between the screening and the surgery.

Eventually, some healthcare workers will likely develop some immunity against SARS-CoV-2, either because they contracted and healed from the disease or, hopefully, because an effective vaccine will become available. While immune testing is not yet reliable,[37,38] its development should allow us to further secure the OR by assigning the care of COVID-19 patients to immune personnel.

DISCUSSION

The COVID-19 pandemic is a crisis of unprecedented proportion in modern healthcare. As we are fighting this battle, it is striking to realize the amount of knowledge that has been produced in the 3 mo since the existence of the SARS-CoV-2 virus was first reported. We already know the complete RNA sequence as well as crystal structure of the virus. Studies are available on mechanisms and sites of entry, virus biodistribution as well as shedding and transmission. Using this understanding, diagnostic tests are being refined, vaccine trials are being organized, and procedures to stop the spread of the virus are being implemented. While not on the frontline of any of these research areas, neurosurgeons can contribute by optimizing their practice to prevent nosocomial infection of patients and healthcare workers. This can be achieved by adapting some steps in neurosurgical procedures to our current understanding of SARS-CoV-2 biology and transmission.

Table 1 summarizes general perioperative measures successfully implemented in Singapore,[5] where the outbreak was exceptionally well controlled.[3] Other similar guidelines have been published and might be of interest to OR managers.[43,50,64]

Table 2 summarizes general measures that are of particular importance to neurosurgeons. These include limiting the number of surgeries performed, limiting the number of individuals in the OR, and performing preoperative testing whenever possible.

Table 3 suggests possible adaptations to standard neurosurgical procedures that have the potential to limit nosocomial transmission. These are aimed at mitigating 3 high-risk settings encountered in the neurosurgical OR: endotracheal intubation and extubation, respiratory or digestive tract exposure, and aerosolization of virion-containing particles.

Given the novelty of the virus, the measures identified above have not been tested in formal trials. They do not constitute binding guidelines and should be seen merely as suggestions to be considered by neurosurgical teams as they navigate this crisis. While they are all based on a biological rationale, their clinical significance remains unproven. Most controversial is the recommendation to limit the use of aerosol-generating instruments, including drills and ultrasonic aspirators. Indeed, the idea that a respiratory virus could be transmitted by inhaling lumbar vertebrae bone dust can be counterintuitive. This would require aerosolization of virion-contaminated blood or CSF with the bone dust, which has never been proven, neither for SARS-CoV-2 nor for SARS-CoV. Definitely, a surgical protocol should not be modified if it compromises patient safety or the intended surgical outcome. Our contention, however, is that in many cases, aerosol-generating instruments can be substituted by other techniques without any negative patient consequences. In these cases, what would be the rationale for not being prudent, given that our understanding of COVID-19 is barely 4 mo old?

We believe that the small proposed changes in the protocols of standard operations could have a significant impact on disease transmission without affecting the surgical outcome of patients. We might never know if they really work, given the numerous

TABLE 3. Neurosurgical Procedure Optimization

• Consider alternatives to general anesthesia whenever possible to minimize the risk of aerosolization associated with endotracheal intubation and extubation ○ For awake surgeries, use a facemask ○ If intubation is required, keep all unnecessary personnel outside of the room during the induction ○ If intubation is required, use neuromuscular blockers to avoid cough
• Consider surgical approaches avoiding the sinuses and mastoids ○ If exposing the nasal or oral mucosa, consider intranasal povidone iodine preparation (especially in endonasal approaches) and chlorhexidine or hydrogen peroxide mouth rinse ○ Avoid postoperative nasal endoscopy and nasal spays
• Given the current uncertainty on the potential of viral transmission through aerosolized blood or other particles such as bone, consider limiting the use of aerosol-generating instruments: ○ Avoid using drills whenever possible: ■ Choose rongeurs, curettes, or chisels instead of burrs, especially when in the vicinity of sinuses or mastoid cells ■ Perform burr holes using a Hudson brace or twist drill rather than a perforator ■ For spinal decompression and stabilization, perform bony removal using rongeurs rather than a burr and use manual, tactile pedicle probes to facilitate the placement of pedicle screws ■ When drilling is required:
• Consider drilling at lower speed • Stop the drill when irrigating • Use large suctions to try and aspirate all airborne particles • Try isolating the drilled area using a transparent adherent film (eg, Opsite™) "tent" or gauzes to limit the spread of airborne particles • Try minimizing the amount of drilling required in spine procedures by using navigation and considering minimally invasive approaches, such as endoscopic procedures and percutaneous instrumentation
○ Avoid using unnecessary electrocautery ○ Avoid using lasers ○ Avoid using ultrasonic aspirators ○ Consider performing VP shunts open rather than laparoscopically to minimize pneumoperitoneum-induced aerosolization ○ Protect the surgical field with towels when hammering to minimize aerosolization ○ Irrigate with large volumes at low pressure rather than low volumes at high pressure

factors in play in this pandemic. What we do know, however, is that if we do not try and mitigate the spread in healthcare workers right now, we will (and already have) lose patients and colleagues in the battle.[40]

CONCLUSION

The SARS-CoV-2 virus has biological properties supporting contact, droplet, and airborne transmission. In the neurosurgical OR, high-risk settings include endotracheal intubation and extubation, procedures involving the respiratory or digestive tracts, and the use of aerosol-generating instruments on virion-contaminated tissues. In addition to supporting general hospital-wide policies, neurosurgeons can contribute to the reduction in the risk of nosocomial infection of healthcare workers by adapting their protocols in COVID-19 patients, high-risk settings, and during local nosocomial outbreaks. Possible changes include postponing all nonurgent cases, reappraising the necessity for GA, considering alternative surgical approaches avoiding the respiratory tract, and limiting the use of aerosol-generating instruments, including drills, electrocautery, ultrasonic aspirators, lasers, and carbon dioxide insufflators.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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Supplemental Digital Content. Methods and ethical considerations are discussed.

10.1093/neuros/nyaa157