Review Article

Neuraxial anaesthesia and peripheral nerve blocks during the COVID-19 pandemic: a literature review and practice recommendations

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Summary

Coronavirus disease 2019 (COVID-19) has had a significant impact on global healthcare services. In an attempt to limit the spread of infection and to preserve healthcare resources, one commonly used strategy has been to postpone elective surgery, whilst maintaining the provision of anaesthetic care for urgent and emergency surgery. General anaesthesia with airway intervention leads to aerosol generation, which increases the risk of COVID-19 contamination in operating rooms and significantly exposes the healthcare teams to COVID-19 infection during both tracheal intubation and extubation. Therefore, the provision of regional anaesthesia may be key during this pandemic, as it may reduce the need for general anaesthesia and the associated risk from aerosol-generating procedures. However, guidelines on the safe performance of regional anaesthesia in light of the COVID-19 pandemic are limited. The goal of this review is to provide up-to-date, evidence-based recommendations or expert opinion when evidence is limited, for performing regional anaesthesia procedures in patients with suspected or confirmed COVID-19 infection. These recommendations focus on seven specific domains including: planning of resources and staffing; modifying the clinical environment; preparing equipment, supplies and drugs; selecting appropriate personal protective equipment; providing adequate oxygen therapy; assessing for and safely performing regional anaesthesia procedures; and monitoring during the conduct of anaesthesia and post-anaesthetic care. Implicit in these recommendations is preserving patient safety whilst protecting healthcare providers from possible exposure.

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Recommendations

1. Planning and preparation

Reduce the clinical load and perform routine testing as per local guidelines. Neuraxial anaesthesia and peripheral nerve blocks are the first choice (whenever possible) for anaesthetic management of patients with suspected COVID-19 infection.

2. Location

Care of COVID-19–infected patients should ideally be provided in the operating area and in an airborne infection isolation room if possible. Patients can be operated in a positive pressure room as long as there are measures to prevent airflow from the operating room into the common areas.

3. Personal protective equipment

Regional anaesthesia procedures are not considered aerosol generating, and therefore droplet precautions are recommended as a minimum. Use of a higher level of precautions (against airborne transmission) may be appropriate when caring for patients under spinal anaesthesia in the operating room in certain situations. Patients should wear surgical facemasks to prevent transmission of COVID-19.

4. Oxygen therapy

The mode of delivery and flow rate of oxygen determines the possibility of aerosol generation and its travelling distance; therefore, the flow of oxygen should be kept to a minimum with the goal to maintain saturation while minimising aerosol generation.

5. Equipment

Minimise the amount of equipment inside the room to what is absolutely essential, and protect the equipment with plastic covers during the procedure.

6. Monitoring and conduct of anaesthesia

Thorough testing for block success is encouraged, to prevent the need for emergency conversion to general anaesthesia. Respiratory monitoring should be ideally performed with the use of viral filters.

7. End of surgery

Patients should be recovered in the operating room or an airborne infection isolation room before being transported to a pre-designated area.

Introduction

The severe acute respiratory syndrome-corona virus-2 (SARS-CoV-2) pandemic has reached unprecedented proportions and has significantly impacted healthcare services and surgical volume. Some of the clinical challenges have resulted from the fact that approximately 80% of infected individuals present with no or only mild symptoms of respiratory infection and that, in the absence of universal testing, clinical screening has not allowed the reliable identification of infected patients [1]. In a recent publication, among 210 asymptomatic women admitted for labour and delivery in New York hospitals, 14% had tested positive for SARS-CoV-2, emphasising the utility of universal testing in communities with a high prevalence of coronavirus-2019 (COVID-19) infection [2].

The virus is highly infectious; the reproductive number (R_0), which represents the number of secondary infections resulting from an infected individual, is thought to be 2.6 (95%CI 1.5–3.5) [3]. However, a recent study suggested that the median R_0 value of COVID-19 may be as high as 5.7 [4]. In an attempt to limit the spread of infection and to preserve healthcare resources, including staffing, operating rooms and anaesthesia machines, elective surgical procedures have been postponed in many countries [5]. However, anaesthesia care is still needed for urgent and emergency surgery.

Similar to previous pandemics, healthcare workers are highly vulnerable to contracting the infection. Hence, strategies to minimise exposure and the risk of disease transmission to healthcare workers or patients in the hospital is crucial. Peri-operative settings and emergency rooms are considered 'hot zones' for disease transmission, and measures to minimise exposure and transmission are vital in these areas [6]. One of the strategies to minimise exposure is to avoid aerosol-generating procedures such as airway management procedures commonly performed in the peri-operative period. General anaesthesia with airway intervention leads to aerosol generation, which exposes the healthcare team to risk of transmission of COVID-19 both during tracheal intubation and extubation [7]. The odds of transmission of acute respiratory infection during tracheal intubation to a healthcare worker are thought to be 6.6 times compared with those who are not exposed to tracheal intubation [8]. Tracheal intubation for a COVID-19–positive patient is ideally performed in a negative pressure room, which may not be available in all places or situations [9]. On the other hand, regional anaesthesia is associated with a lower risk of postoperative complications, and this becomes more important in the context of ongoing respiratory infection [10, 11].

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Regional anaesthesia may be the preferred choice for providing anaesthesia care when possible, as it can provide an alternative safe anaesthetic care plan by avoiding the need for aerosol-generating procedures. Secondly, in the light of expected anaesthetic drug shortages during this pandemic, regional anaesthesia may spare the need for sedatives and hypnotics and hence is less resource-intensive compared with general anaesthesia. Despite previous respiratory pandemics such as SARS in 2003 and Middle East respiratory syndrome (MERS) in 2012, there is very little evidence-based guidance available for the practice of regional anaesthesia. An urgent need for such guidelines has been suggested by practising anaesthetists [12].

Our group recently published an interim joint statement by the American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anaesthesia and Pain Therapy for the practice of regional anaesthesia during the COVID-19 pandemic [13]. The current paper aims to provide more detailed, evidence-based practice recommendations for the safe performance of regional anaesthesia applicable to the current COVID-19 pandemic.

Methods

A three-step approach was employed, which included a formal literature search followed by hand searches on individual domains, following which recommendations were generated through mutual consensus. The domains of interest were: planning of resources and staffing; modifying the clinical environment; preparing equipment, supplies and drugs; selecting appropriate personal protective equipment (PPE); providing adequate oxygen therapy; assessing for and safely performing regional anaesthesia procedures; and monitoring during the conduct of anaesthesia and post-anaesthetic care.

Firstly, a formal literature search was performed for evidence on the use of regional anaesthesia during respiratory pandemics. This was conducted by an experienced librarian (DC) and included PubMed, Embase and the Cochrane Library. The searches were limited to the English language, humans and to a publication date between 1 January 2000 and 9 April 2020. The terms COVID-19 (or SARS or H1N1 or MERS); anesthesia (or anaesthesia, or anaesthetics or anesthetics); surgery; and/or operating rooms were used for the search (see online Appendix S1). This search aimed to explore all the literature pertinent to the practice of regional anaesthesia during COVID-19 or similar outbreaks. Specific populations, interventions or outcomes were not added to keep the search broad to include surgical anaesthesia and analgesia.

The titles and abstracts were screened by two authors independently (VU/HK) to select all publications providing recommendations or reporting on the use of regional anaesthesia for a surgical procedure in the context of respiratory infection epidemic caused by viruses similar to SARS-CoV-2 (SARS; H1N1; MERS). Any conflicts were resolved by consensus. Backward reference searching was conducted for the selected articles to ensure any essential references were not missed. Full texts of all the selected articles were reviewed in detail, and points relevant to neuraxial and regional anaesthesia were extracted.

Since the formal literature search revealed a paucity of evidence to make any conclusive recommendations, hand searches were performed by the authors to look for either clinical or laboratory evidence on the individual domains relevant to the practice of regional anaesthesia. The literature evidence was further supplemented by professional society guidelines and landmark articles important to the practice of regional anaesthesia. With the collected literature evidence as the basis, practice recommendations were derived through mutual consensus after iterative discussion among the authors.

Results

The literature search identified 987 articles. After title and abstract screening, 16 papers were selected for full-text review; among those, there was one retrospective cohort study [14]; four case series [15-18]; four case reports [19-22]; and seven expert opinion articles [1, 12, 23-27] (Table 1). Backward citation identified additional reports; however, the information relevant to regional anaesthesia was already presented in original papers in the initial search. An additional case series was identified by a co-author (RL) during the process of manuscript preparation and was included [28]. The overall quality of evidence was moderate to low, with most studies being single-centre cohort studies, case-control studies, case series or case reports. There was very little evidence available from the 17 selected publications regarding oxygen therapy, PPE or the conduct of regional nerve blocks (Fig. 1). Recommendations on these aspects were mainly obtained based on the hand searched articles and society guidelines. The overall quality of evidence was low, and hence the strength of the recommendations is moderate to weak.

Discussion

The highest available level of evidence relevant to the practice of regional anaesthesia is summarised below

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Table 1 Summary of publications reporting on regional anaesthetic or neuraxial procedures in patients with COVID-19 infection.

Study	Type	Findings
Altiparmak et al. [12]	Letter to editor	Neuraxial anaesthesia and peripheral nerve blocks should be the first choice (whenever possible) for anaesthetic management of patients with suspected COVID-19 infection. Need for a regional anaesthesia guideline in patients with COVID-19 infection.
Aminnejad et al. [27]	Letter to editor	Debates safety of general anaesthesia vs. neuraxial anaesthesia
Bauer et al. [16]	Case series (n = 14)	No reported neurological sequelae after neuraxial procedures in 14 obstetric patients with COVID-19 infection with varying severity of the infection. Thrombocytopenia was reported in two pregnant patients without pre-eclampsia. Suggests that the risk of causing meningitis or encephalitis is extremely low with neuraxial procedures, even in infected patients.
Bauer et al. [15]	Expert opinion	Early labour epidural analgesia recommended. Maternal hypotension during caesarean delivery with epidural or spinal anaesthesia has not been noted.
Breslin et al. [28]	Case series (n = 18)	Eighteen cases with neuraxial anaesthesia in obstetric patients (either using intrapartum epidural analgesia, spinal or combined spinal-epidural anaesthesia). None had contra-indications (such as thrombocytopenia or sepsis) to the neuraxial procedure, no haemodynamic instability was noted in any of the patients, and no neurological complications were observed.
Chen et al. [17]	Case series (n = 14)	Twelve out of the 14 parturients (86%) undergoing epidural anaesthesia experienced a higher rate of intra-operative hypotension when 2% lidocaine was used for a loading dose, and 0.75% ropivacaine was used for maintenance. Recommends elective caesarean delivery under neuraxial anaesthesia wherever possible to reduce the possibility of pulmonary complications secondary to intubation.
Cohen et al. [25]	Expert opinion	Epidural or paravertebral catheter insertion or epidural blood patch (if indicated) should not be postponed for a COVID-19 positive patient.
Landau et al.[1]	Letter to editor	Pathophysiological changes in pregnancy make interpretation of screening results difficult. Tracheal intubation in one patient was reported to have precipitated immediate, prolonged bronchospasm. Treatment of bronchospasm (nebulisation) could possibly cause aerosolisation of viral particles.
Lee et al. [19]	Case report (for H1N1)	H1N1 and superimposed bilateral pneumonia. Epidural analgesia for labour followed by vaginal delivery. No complications reported.
Lee et al. [20]	Case report	Caesarean delivery; hypotension after spinal anaesthesia stabilised after a few boluses of phenylephrine. The placenta, amniotic fluid and cord blood were all negative for SARS-CoV-2 PCR test.
Lie, et al. [23]	Expert opinion	The patient should be assessed, the block performed and the patient allowed to recover, inside the operating room where the surgery will be performed to limit contamination to a single location. Consider digital consent to reduce potential paper contamination. The ultrasound machine's screen and controls protected with a single-use plastic cover. The CO_2 sampling line can be connected to a 15-mm tracheal tube connector and a high-efficiency particulate air and heat and moisture exchange filters. Healthcare professional involved in performing regional anaesthesia on a COVID-19 patient should, at minimum, don PPE, goggles and a surgical facemask. Attempt to minimise diaphragmatic paralysis by modifying the local anaesthetic dose via volume and concentration or the injection site or technique.
Maxwell et al. [24]	Expert opinion (for SARS)	Neither epidural nor spinal anaesthesia is contra-indicated.
Park et al. [21]	Case report (for MERS)	Emergency caesarean delivery for placental abruption. Use of level 3 PPE (airborne precautions) and negative pressure room.
Shanthanna, et al. [26]	Expert opinion	The duration of immunosuppression may be shorter with dexamethasone and betamethasone compared with other commonly used steroids used as adjuvants.
Xia et al. [22]	Case report	Spinal anaesthesia for emergency caesarean delivery in a patient with moderate to severe COVID-19 disease. No complications reported. Level 3 PPE (airborne precautions) used
Zhao et al. [18]	Case series (n = 11)	Eleven patients received spinal anaesthesia for non-obstetric surgery. No reported anaesthesia-related complications.

(continued)

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Table 1 (*continued*)

Study	Type	Findings
Zhong et al. [14]	Observational cohort study	Spinal anaesthesia for 45 caesarean delivery and four orthopaedic procedures was well tolerated, with no unusual complications. Level 3 PPE (airborne precautions) appear to reduce the risk of transmission to anaesthetists compared with level 1 PPE (contact precaution)

SARS, severe acute respiratory syndrome; MERS, Middle East respiratory virus; PPE, personal protective equipment; SARS-CoV-2, severe acute respiratory syndrome-coronavirus-2; PCR, polymerase chain reaction.

under each heading. Although the level of evidence is low for the majority of the above interventions, these recommendations provide a summary of the best available evidence and discuss some uncertainties. The following recommendations apply to a patient with either a suspected or confirmed COVID-19 infection.

Planning and preparation

Recommendations

Reduce the clinical load and perform routine testing as per local guidelines [29]. Neuraxial anaesthesia and peripheral nerve blocks are the first choice (whenever possible) for anaesthetic management of patients with suspected COVID-19 infection [12].

Reducing the volume of surgical procedures allows time for institutions to: plan for a surge of patients with COVID-19; preserve existing stock of PPE; and plan staffing appropriately, particularly as healthcare workers will be quarantined or unwell themselves [30, 31]. This is based on previous governmental regulations implemented during pandemics [32]. All elective operations should be postponed to reduce the risk of exposure of patients and healthcare workers to COVID-19 and to conserve the capacity of the healthcare system, personnel and resources for a possible increase in demand [29]. Therefore, anaesthesia care should be reserved for urgent and emergent surgery. Guidance for triage of non-emergent surgical procedures may vary in different countries and may change during the course of the pandemic [33].

Encourage the use of neuraxial anaesthesia and peripheral nerve blocks as the first choice (whenever possible) for anaesthetic management of patients with suspected COVID-19 infection. Careful consideration should be given to allow the surgery to be performed entirely under regional anaesthesia. An unplanned need for intra-operative conversion to general anaesthesia is the least desirable outcome. This requires excellent communication between the patient, anaesthetist and the surgical team.

During the COVID-19 pandemic, preparation for anaesthesia and surgery sometimes entails screening all patients and determining the COVID-19 status (e.g. COVID-19 positive, suspected positive (could be under investigation)) [34]. If the community spread is low and a patient is asymptomatic or if tested COVID-19 negative, then regional anaesthesia can be provided following usual local institutional guidelines as before the pandemic. If the community spread of COVID-19 infection is significant, all asymptomatic patients should be presumed to be COVID-19 positive if no testing is being done or while test results are pending.

The possibility of false-negative results should always be kept in mind. Data have suggested that there is significant variability in the comparative accuracy of different diagnostic modalities, and thus a high index of suspicion and maximising safety procedures is prudent [35]. It is estimated the infection attack rate (the probability of becoming infected) could reach 50–80% of the population, and until evidence suggests that it is safe to presume otherwise, all patients should be presumed to have COVID-19 infection [36].

Location

Recommendations

Care of COVID-19–infected patients should ideally be provided in the operating area and in an airborne infection isolation room if possible. Patients can be operated in a positive pressure room as long as there are measures to prevent airflow from the operating room into the common areas.

If available, the care of patients with confirmed or suspected COVID-19 infection should be provided in a negative pressure room. Nevertheless, surgeries have been safely performed in positive pressure rooms during the SARS outbreak and currently during the COVID-19 pandemic [37]. There is a theoretical risk of spreading the aerosolised particles to the corridors outside the operating room in a positive pressure room. However, operating rooms have a higher air exchange rate compared with hospital wards or floors. With a standard operating room with a minimum of 15 air exchanges per hour, 99% and 99.9% of airborne contaminants will be removed in 18 min

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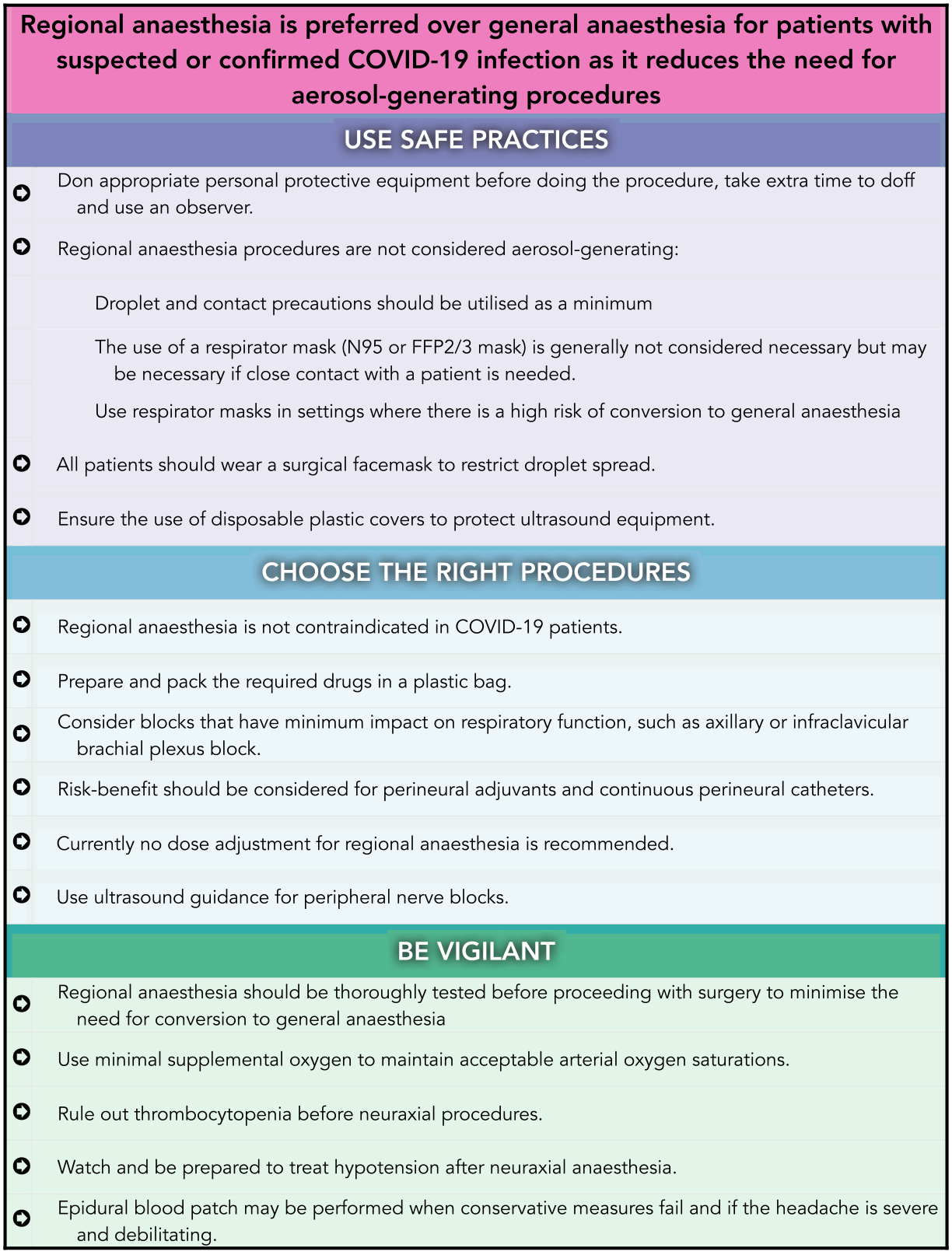

Figure 1 Key recommendations for the performance of regional anaesthesia in suspected or confirmed COVID-19 patients.

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Recommendations for personal protective equipment for regional anaesthesia in a patient with suspected or confirmed COVID-19 infection.

- The recommendations below assume that the main route of transmission is through contact and droplet routes, but if there is a change in evidence regarding the route of transmission, a higher level of personal protective equipment should be considered.
- These recommendations also assume that the patient is advised to wear a surgical facemask at all times during regional anaesthesia procedure and surgery.
- Use a higher level of personal protective equipment in case of uncertainty in oxygen requirement, duration of close contact or block success.
- Always have respirator masks available, as the intra-operative course may vary during the case.

LEVELS OF PERSONAL PROTECTIVE EQUIPMENT*

- **Contact precautions**: Fluid resistant gowns + gloves
- **Droplet precautions**: Fluid resistant gowns + gloves + face shield/goggles + fluid-resistant face mask
- **Airborne precautions**: Fluid resistant gown + gloves + face shield/goggles + respirator mask (N95 or FFP2/ FFP3)/ PAPR

RECOMMENDATIONS

Pre-operative assessment	Droplet precautions
Head and neck blocks	Droplet precautions Consider airborne precautions
Upper limb block	Droplet precautions Consider airborne precautions
Lower limb block	Droplet precautions
Central neuraxial block	Droplet precautions
Intra-operative monitoring	Droplet precautions Healthcare professionals should attempt to maintain a 2 m distance from the patient if possible. Consider airborne precautions if: The patient is unable to wear a surgical facemask Significant risk of intra-operative conversion to general anaesthesia Surgical procedure could be aerosol-generating
Oxygen therapy	Droplet precautions if oxygen flow < 5 l.min-1 and the patient is wearing a facemask. Airborne precautions if high-flow oxygen is used
Equipment protection and decontamination	Cover the ultrasound machines with transparent plastic drapes which can be safely removed. Wipe the ultrasound machine after removing the covers. Allow time for the disinfectant to dry.

PPE, personal protective equipment; PAPR, powered air-purifying respirator.
*Inconsistency of nomenclature with regards to the level of PPE in literature. Commonly used terminology: level-1 PPE = contact precautions, level-2 PPE = droplet precautions and level-3 PPE = airborne precautions.

Figure 2 Recommendations for personal protective equipment for regional anaesthesia in a patient with suspected or confirmed COVID-19 infection.

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and 28 min, respectively [38]. Alternatively, another report suggests decreasing the inflow while increasing the exhaust can enable the room to remain at neutral pressure while still maintaining laminar flow over the surgical area [37].

The regional anaesthesia procedure for a patient with suspected or confirmed COVID-19 infection should be performed in the operating room, or a labour room for an obstetric patient. The use of common areas, such as a block room or a holding area, should be avoided to reduce the risk of cross infection. If possible, record keeping or electronic recordings should be done outside the room.

Personal protective equipment

Recommendations

Regional anaesthesia procedures are not considered aerosol-generating, and therefore droplets precautions are recommended as a minimum (Fig. 2). Use of a higher level of precautions (airborne precautions) may be appropriate when caring for patients under spinal anaesthesia in the operating room in certain situations (Fig. 2). Patients should wear surgical facemasks to prevent transmission of COVID-19.

Protection of healthcare workers when caring for a patient during the COVID-19 pandemic necessitates appropriate PPE, especially in light of PPE shortages. An appropriate level of PPE is determined by both the medical procedure and the proximity of a healthcare worker to the patient. Personal protective equipment can be classified into three levels (Fig. 2): contact precautions; droplet precautions; and airborne precautions [39]. A healthcare worker caring for a suspected or confirmed COVID-19 patient within 2 m should use droplet precautions if the procedure is not an aerosol-generating procedure.

In a small, retrospective, cohort study, airborne precautions reduced the transmission risk to anaesthetists exposed to mildly symptomatic surgical patients during spinal anaesthesia when compared with contact precautions [14]. Of importance, neither neuraxial anaesthesia nor peripheral nerve blocks are considered to be aerosol-generating procedures; therefore, applying regular contact and droplet precautions for these low-risk procedures suffice [40]. Personal protective equipment includes a surgical mask, eye protection (goggles or face shield), an impervious surgical gown, and gloves for personnel involved in performing these procedures. The use of respirator masks (e.g. N95 or FFP2/3) is not generally needed but may be considered for prolonged close contact with a COVID-19–infected patient in a closed environment [41].

Keeping this in mind, if the chances of intra-operative conversion to general anaesthesia are significant with the need for airway intervention (an aerosol-generating procedure), it may be appropriate to use a respirator mask. The anticipated urgency and probability of conversion to general anaesthesia is an essential factor when making the decision to wear a respirator mask. Importantly, all patients should wear a surgical mask to restrict the droplet spread [42]. The most experienced person should perform the regional anaesthesia technique. The donning of PPE should occur before entering the room. The presence of an observer during the donning and doffing procedure is highly recommended. Simulation sessions should be conducted for training staff in donning and doffing of PPE [34].

Much confusion exists among providers as to: what the levels of PPE mean; whether the route of transmission is airborne or droplets and contact; and what is the difference between aerosol vs. droplet vs. droplet nuclei vs. airborne. Some of these concepts have been clarified in a recent review [39]. Such controversies existed in previous pandemics too. Several independent risk factors have shown to be responsible for nosocomial transmission of SARS, and the same may hold true for COVID-19. These include: a distance between beds of less than 1 m; resuscitation attempts; presence of symptomatic caregivers; the need for oxygen therapy; or non-invasive positive pressure ventilation. While many of these domains may not be relevant to the practice of regional anaesthesia, oxygen therapy needs consideration.

Oxygen therapy

Recommendations

The mode of delivery and flow rate of oxygen determines the possibility of aerosol generation and its travelling distance, therefore; the flow of oxygen should be kept to a minimum with the goal to maintain saturation while minimising aerosol generation.

Oxygen supplementation can result in exhaled air jets and may result in droplet nuclei formation. Whether or not this may result in respirable infectious aerosols depends on a variety of factors, such as: the type of oxygen therapy utilised; the viral load in each breath; ventilation and air exchange in the room; and the use of facemask by the patient, among others. The type of oxygen therapy determines the travelling distances of the exhaled air with the least distance (0.4 m) seen with the use of a Hudson mask utilising 4 $l.min^{-1}$ of oxygen flow [43], followed by nasal cannula 1 m caudally with the use of 5 $l.min^{-1}$ of oxygen flow [44] and probably the maximum by a jet nebuliser (> 0.8 m laterally) when using 6 $l.min^{-1}$ oxygen flows [45].

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The presence of an exhaled jet does not necessarily translate into the presence of respirable droplet nuclei or aerosols, as these studies have been conducted using smoke plumes rather than actual detection of infectious aerosols. Also, the concentration of airborne particles is known to decrease over distance, irrespective of other factors such as airflow [46]. It is a common practice to protect the mouth and nose of patients with respiratory infection as this may reduce person-to-person transmission of respiratory infectious viruses. Surgical masks seem to be as effective as respirator masks in decreasing transmission of nosocomial and healthcare worker infections [47].

Based on the above evidence, the use of high oxygen flows through nasal cannulae should be avoided to reduce the risk of possible aerosol generation [48]. If the patient needs supplemental oxygen, an oxygen mask should be preferred over nasal prongs. The flow of supplemental oxygen should be kept to the minimum (preferably < 5 l.min^{-1}) needed to maintain arterial oxygen saturation to reduce the risk of aerosolisation [49]. Surgical facemasks can be used over oxygen masks to limit the dispersion of droplets.

Equipment

Recommendation

Minimise the amount of equipment inside the room to what is absolutely essential, and protect the equipment with plastic covers during the procedure.

The required equipment and drugs for immediate peri-operative care should be prepared and packed in a plastic bag [50]. The ultrasound equipment, including an ultrasound transducer, should be protected from contamination using plastic covers [23]. Handheld ultrasound devices are preferable to larger units for suspected or confirmed COVID-19 patients. If using trolley-based ultrasound machines, extra attachments such as baskets and printers should be removed. Single-use ultrasound gel packs are preferable over multi-use gel bottles. Bringing a cart or trolley with drugs and equipment to the procedure room should be discouraged. The number of personnel present during the performance of the procedure should be minimised, but help (e.g. a 'runner') should be readily available.

There is evidence demonstrating that COVID-19 virus particles could remain viable on plastic for up to 3 days [51]. However, as most available disinfectants are effective against SARS-CoV-2, it is recommended that the ultrasound machine be wiped twice, once inside the room and then again outside the room. Adequate time should be given to allow the surface to dry after each wipe [52]. Institutional protocols should be used for decontamination of equipment.

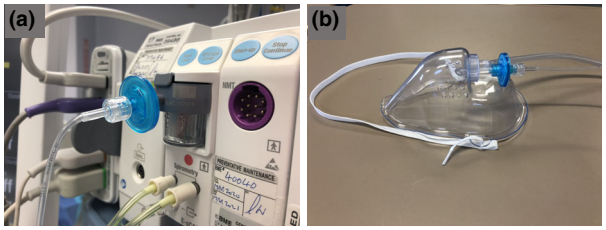

Figure 3 Possible arrangements to allow the re-use of capnography sampling tubing between patients. (a) A membrane filter between the CO_2 line and water trap. (b) A membrane filter connected to the CO_2 line at the mask end of tubing.

Neuraxial procedures

Recommendations

Presence of COVID-19 infection in itself is not a contra-indication to performing neuraxial anaesthesia. It is advisable to rule out thrombocytopenia before attempting neuraxial techniques in a suspected or confirmed COVID-19 patient.

Management of obstetric patients with suspected or confirmed COVID-19 during labour and delivery requires specific considerations [21]. The crucial physiological difference and urgency should be taken into consideration when making decisions regarding neuraxial procedures in pregnant women. Assessment of the suitability of neuraxial procedures requires balancing the risks of general anaesthesia. A factor that should be taken into consideration is the presence of any pre-operative respiratory compromise that may deteriorate due to further loss of functional residual capacity after neuraxial anaesthesia.

Preliminary evidence suggests that thrombocytopenia might occur in patients with severe COVID-19 disease [53], while other data demonstrate lower platelet counts in COVID-19 positive patients compared with COVID-19 negative patients [54, 55]. It is therefore advisable to rule out thrombocytopenia before attempting neuraxial techniques in a COVID-19–positive or suspected patient. A platelet count of $75{,}000 \times 10^6$.l^{-1} or above has been suggested as an acceptable level for performing of neuraxial procedures in the obstetric population, provided the platelet function is expected to be normal [56].

The use of neuraxial procedures during pregnancy and delivery was reported in early studies from China. A recent review described 14 cases of neuraxial anaesthesia for delivery pooled from four different reports [16]. Fever was reported in all patients, but none had a high white cell

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count, except one that was attributed to the concomitant use of methylprednisolone for unrelated inflammatory conditions. In general, the presence of COVID-19 infection in the absence of any other risk factors or laboratory abnormality is not a contra-indication for neuraxial procedures in obstetric or non-obstetric patients with COVID-19 infection [18, 22]. Routine indications and contra-indications for neuraxial anaesthesia apply when managing suspected or confirmed COVID-19 patients.

In a cohort of obstetric patients in New York, tested positive for COVID-19 infection, among 18 consecutive women receiving neuraxial labour analgesia or anaesthesia for caesarean delivery, none had a contra-indication (e.g. thrombocytopenia or sepsis) for a neuraxial procedure, no haemodynamic instability was reported during the surgery, and no neurological complications were noted in the postpartum period [28].

Caution should be exercised when attempting to reduce the duration of the spinal anaesthetic by using short-acting spinal anaesthetics or reducing the dose of the spinal anaesthetic agent, as conversion to general anaesthesia is the least desirable outcome. Routine asepsis techniques being practised for non-COVID patients should still be followed. If available, an epidural positioning device could be used to reduce the contact of the assistant with a suspected or confirmed COVID-19 patient. Currently, no dose adjustment for spinal anaesthesia or adjuvant opioids is recommended. However, a change to the epidural infusion regimen may be needed to reduce the need for additional top-up doses that require frequent patient contact.

A single, small case series suggested the possibility of excessive intra-operative hypotension when prophylactic vasopressors were not used [17]; however, hypotension following neuraxial anaesthesia has not otherwise been reported. Anaesthetists should be prepared to manage hypotension following neuraxial procedures as for any other patient [57, 58].

Management of post-dural puncture headache

Recommendations

As with usual care, pharmacological approaches should be proposed before performing an epidural blood patch. Complications should be discussed on a case-by-case basis.

There are currently no available data to guide the management of post-dural puncture headache (PDPH) in patients with COVID-19 infection. Pharmacological approaches should be proposed as with any other patient. Concern about the injection of viraemic blood into the epidural space with an epidural blood patch has been raised, especially during active illness, although there is currently no evidence to suggest that this may be the case. If the PDPH is severe and debilitating, an epidural blood patch should be proposed, balancing the risk of neurological complications associated with severe untreated PDPH against the theoretical risk associated with the injection of possibly viraemic blood in the epidural space [25].

Nasal sphenopalatine ganglion block might be an aerosol-generating procedure, as it involves an injection/insertion into the nasal cavity, and may increase the risk of COVID-19 transmission to healthcare workers. Therefore, it should be avoided in patients with suspected or confirmed COVID-19.

Peripheral nerve block

Recommendations

If performing a peripheral nerve block near the head and neck area, in addition to droplet precautions, precautions against airborne virus transmission may be considered. Use ultrasound guidance to reduce the risk of local anaesthetic systemic toxicity.

The evidence regarding the use of peripheral nerve blocks is minimal. Recently, Lie et al. published practical considerations for performing regional anaesthesia, and the American and European Societies of Regional Anaesthesia have published a practice recommendation on the topic [13, 23]. In general, peripheral nerve blocks are considered to result in fewer physiological consequences or haemodynamic side-effects compared with neuraxial techniques. Most peripheral nerve blocks do not cause sympathectomy leading to hypotension. In terms of the risk of haematoma, a few deep peripheral nerve blocks are considered similar but still are less likely to cause compressive symptoms as the peripheral nerves are not enclosed in a spinal canal.

Patient preparation and asepsis should be similar to that followed for the neuraxial procedure. If possible, attempts should be made to choose the block that is least likely to interfere with respiratory function. In other words, axillary or infraclavicular brachial plexus block may be chosen over supraclavicular brachial plexus block, and superior trunk block or other alternatives are preferred over interscalene block.

The dose of pre-procedural sedation, if used, may need to be reduced to avoid any respiratory compromise requiring supplemental oxygen. A safe dose of local anaesthetics should be calculated and used. Blocks should be performed with ultrasound guidance to reduce the risk of local anaesthetic systemic toxicity [59]. The benefit of perineural adjuvants must be balanced against the risks of

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immunosuppression (dexamethasone); sedation; bradycardia and hypotension (clonidine and dexmedetomidine); drug errors; and drug contamination [26].

The decision to insert and maintain perineural catheters needs to be made on a case-by-case basis. While continuous catheter techniques can be labour- and resource-intensive and may require frequent patient contact, the opioid-sparing effect of regional anaesthesia can be beneficial to a patient with respiratory morbidity. Hence, the use of inpatient perineural catheters should be evaluated based on patient needs and available resources. Ambulatory perineural catheters may still be utilised with clear patient instructions.

Similarly, the risk-benefit ratio of analgesic peripheral nerve blocks and fascial plane blocks should be evaluated on a case-by-case basis. If the block is performed under general anaesthesia and requires repositioning of the patient, there is a risk of tracheal tube disconnection or dislodgement. Therefore, it may be advisable to choose a block that does not require patient repositioning (e.g. transversus abdominis plane blocks) over those that require repositioning (e.g. erector spinae plane block), if appropriate. In general, any additional analgesic block procedures should be avoided if adequate analgesia can be achieved using alternate regimens such as systemic analgesia. If the patient is not wearing a surgical mask during an upper limb procedure, the patient can be requested to turn the head away from the operator or plastic drapes can be used to limit droplet spread to the anaesthetist.

Monitoring and conduct of anaesthesia

Recommendations

Thorough testing for block success is encouraged to prevent the need for emergent conversion to general anaesthesia. Respiratory monitoring should be ideally performed with the use of viral filters.

Both neuraxial anaesthesia and peripheral nerve block should be thoroughly tested for block success before proceeding with surgery to minimise the risk of conversion to general anaesthesia. In the case of peripheral nerve block, extra onset time should be allowed to reduce the risk of conversion. If intra-operative conversion to general anaesthesia is required, the emergency airway procedure should be followed, as described in the literature [49]. Excessive or deep sedation should be avoided to reduce the need for any airway manipulation or interventions.

Our current understanding of COVID-19 spread suggests that coughing and sneezing lead to the generation of droplets. However, the patient should wear a surgical facemask at all times throughout the procedure. Prolonged close contact with a suspected or confirmed COVID-19 patient should be avoided wherefore possible.

There are concerns about anaesthetic machine contamination by the virus via end-tidal carbon dioxide monitoring, as the carbon dioxide sample line draws the gas sample directly without passing through a heat and moisture exchange filter. The contaminated gases generally enter the gas analyser through a water trap. The water trap of the anaesthesia machines includes a filter that typically filters approximately 99.999% of viruses. The filtering capacity of each filter can be obtained from the instruction manual provided by the manufacturer. However, the disposal of the water trap filter is recommended after use for an infected patient. Alternatively, use of a 0.2-micron membrane filter (Fig. 3), epidural filter or heat-moisture exchange filters can potentially allow the re-use of the water trap between the patients [23, 60].

End of surgery

Recommendations

Patients should be recovered in the operating room or an airborne infection isolation room before being transported to a pre-designated area.

The patient should be monitored in the operating room until safe and before transfer to a COVID-19 designated area of the hospital, in accordance with local guidelines. It has been shown that the risk of transmission is highest during the doffing of PPE, therefore extra time should be allowed for donning and doffing [61, 62]. Any re-usable equipment utilised during the procedure should be disinfected as per institutional guidelines.

Limitations of the review and future directions

The dearth of robust evidence precludes making any strong practice recommendations, despite the COVID-19 pandemic not being the first respiratory pandemic in the last two decades. Current evidence has been generated through individual case series or a retrospective cohort of cases from single institutions. National and societal registries will provide additional data to guide safe practices in the coming months [63, 64]. Individual experiences are vital in formulating treatment plans in the light of an epidemic, and a similar learning lesson was seen during the SARS outbreak when the contributions of the frontline workers and a grounded theory approach helped in formulating a risk management framework and management guidelines for the safe performance of aerosol-generating procedures [65]. A similar effort is

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needed to generate evidence-based practice recommendations in regional anaesthesia. Future evidence on the disease course may change our recommendations.

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Supporting Information

Additional supporting information may be found online via the journal website.

Appendix S1. Search strategy.

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