SPECIAL ARTICLE

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Personal protective equipment and evidence-based advice for surgical departments during COVID-19

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Abstract

Background: Inconsistencies regarding the use of appropriate personal protective equipment (PPE) have raised concerns for the safety of surgical staff during the coronavirus disease 2019 (COVID-19) pandemic. This rapid review synthesizes the literature and includes input from clinical experts to provide evidence-based guidance for surgical services.

Methods: The rapid review comprised of targeted searches in PubMed and grey literature. Pertinent findings were discussed by a working group of clinical experts, and consensus recommendations, consistent with Australian and New Zealand Government guidelines, were formulated.

Results: There was a paucity of high-quality primary studies specifically investigating appropriate surgical PPE for healthcare workers treating patients possibly infected with COVID-19. SARS-CoV-2 is capable of aerosol, droplet and fomite transmission, making it essential to augment standard infection control measures with appropriate PPE, especially during surgical emergencies and aerosol-generating procedures. All biological material should be treated a potential source of SARS-COV-2. Staff must have formal training in the use of PPE and should be supervised by a colleague during donning and doffing. Patients with suspected or confirmed COVID-19 should wear a surgical mask during transfer to and from theatre. Potential solutions exist in the literature to extend the use of surgical P2/N95 respirators in situations of limited supply.

Conclusion: PPE is advised for all high-risk procedures and when a patient's COVID-19 status is unknown. Surgical departments should facilitate staggered rostering, remote meeting attendance, and self-isolation of symptomatic staff. Vulnerable surgical staff should be identified and excluded from operations with a high risk of COVID-19 infection.

Introduction

Coronavirus disease 2019 (COVID-19) was first identified in December 2019 in the city of Wuhan, China,[1] and rapidly developed into a global pandemic.[2] The novel human coronavirus responsible has since been named severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2).[3]

SARS-CoV-2 particles are spherical, with a diameter of 60–140 nm.[4] The virus is capable of aerosol, droplet and fomite transmission, and, depending on the inoculum shed, can remain viable in aerosols for up to 3 h and on surfaces for up to 3 days.[5] Asymptomatic carriers of COVID-19[6] can create substantial undocumented infection, facilitating rapid human-to-human transmission and geographical spread.[7] Given its size, multiple modes of

transmission and ease of transmission, standard infection control measures against SARS-CoV-2, while still necessary, are inadequate for preventing its spread, especially within healthcare settings.

Healthcare workers (HCWs) are at significant risk of COVID-19 infection,[8–10] however, the correct use of personal protective equipment (PPE) will mitigate this risk.[11] Appropriate PPE is especially important in surgical care, where the potential exposure to biohazardous material places staff at a significant risk of contracting infectious diseases from patients.[12–14]

PPE comprises a variety of garments or other safety equipment worn for the protection of HCWs, including disposable gowns, aprons, gloves, face shields, goggles, outer foot coverings, head coverings, surgical masks, filtering facepiece respirators (FFRs) and powered air-purifying respirators.[15] However, PPE is only effective if used correctly and appropriately. This was demonstrated in the 2003 severe acute respiratory syndrome virus (SARS) outbreak, where improper or inconsistent use of PPE was significantly associated with HCW SARS infection.[16–19]

This rapid review aims to provide evidence-based guidance on the appropriate use of PPE for the safety of surgical staff.

Methods

The working group responsible for this evidence-based guidance consisted of expert general surgeons, with additional advice from representatives from three specialty colleges and one surgical association within Australia and New Zealand.

Royal Australasian College of Surgeons researchers affiliated with the Australian Safety and Efficacy Register of New Interventional Procedures – Surgical, and Research, Audit and Academic Surgery conducted a rapid review of the literature,[20–22] consisting of targeted searches of the PubMed database and grey literature. Collation of evidence, literature review and in-depth discussions with the working group members produced consensus recommendations on PPE[23] in harmony with the Australian and New Zealand Government Departments of Health's PPE guidelines.

Table 1 Recommendations from the working group on personal protective equipment (PPE) for surgical staff during COVID-19 (5 May 2020)[26]

Implement mandatory infectious disease control training for all surgical staff
Implement mandatory PPE donning and doffing training for all surgical staff
Develop contingency plans to extend the use of PPE, especially P2/N95 respirators
Where possible, patients with severe respiratory symptoms and/or suspected or confirmed COVID-19 to wear surgical masks during transfer
PPE for procedures that are not aerosol-generating:
• Surgical mask
• Disposable gown
• Disposable double sterile gloves
• Eye protection (safety glasses, goggles or full-face shield)
• Head covering
• Shoe covering
• Proper hand hygiene
PPE for aerosol-generating procedures:
• Surgical P2/N95 respirator†
• Disposable fluid-impervious long-sleeved gown
• Disposable fluid-impervious apron†
• Disposable double sterile gloves
• Eye protection (safety glasses, goggles or full-face shield)
• Bouffant head covering
• Disposable impervious shoe covering
• Proper hand hygiene
PPE for emergency surgery‡:
• Treat patient as COVID-19-positive until diagnostic tests indicate otherwise
• Surgical staff to don the same PPE as worn for aerosol-generating procedures
PPE for category 1 elective surgery§:
• If patient is COVID-19-positive, surgical staff to don the same PPE as worn for aerosol-generating procedures
• If patient confirmed COVID-19 negative, surgical staff to don PPE as outlined by the surgical unit of their individual healthcare facility

†Additional items.

‡Performed within 24 h of presentation, where there is inadequate knowledge of patient medical history, travel history or COVID-19 status.

§Performed within 1 month of presentation.

Results and discussion

At the time of this publication, the epidemiology of COVID-19 is still unclear.[24,25] The use of PPE is situational and influenced by jurisdiction and access to medical resources. As such, the recommendations developed here (Table 1) consider the variability within different clinical situations, the supply of and access to PPE, and the COVID-19 status of the surgical patient being treated. Individual surgical teams may adapt this guidance to suit their clinical and resource environments.

For individual healthcare centres within Australia, it is recommended that the advice on PPE provided in this publication is supplemented with that issued by the Australian Government Department of Health.[27] Similarly, healthcare centres within New Zealand should also refer to the Ministry of Health, New Zealand, for guidance.[28]

Biodistribution of COVID-19

Several small observational studies have demonstrated the presence of SARS-CoV-2 viral particles in various organ systems. A study of 205 COVID-19 patients by Wang *et al*.,[29] investigated the biodistribution of SARS-CoV-2 RNA using real-time reverse transcription-polymerase chain reaction (RT-PCR). They reported that bronchoalveolar lavage fluid showed the highest positive rates, followed by sputum, nasal swabs, fibrobronchoscope brush biopsy, pharyngeal swabs, faeces and blood, but it was not detected in urine specimens. Stool samples from four patients with high viral RNA loads were cultured and subjected to scanning electron microscopy and live SARS-CoV-2 particles were found in two of the four samples. It was noted that these two viral-positive patients did not have diarrhoea. Similarly, Xiao *et al*.,[30] found infectious virus isolated from faeces and gastrointestinal epithelial cells that stained positive for the nucleocapsid protein of SARS-CoV-2. The virus continued to be detected from faeces of 20% of patients testing negative for viral RNA in the respiratory tract post-infection. The current evidence indicates that all biological material should be treated as a potential source of SARS-CoV-2, and surgical staff should take

precautionary measures when donning (putting on) and doffing (removing) PPE.

COVID-19 testing and PPE

The literature reporting different testing methods for COVID-19 is still embryonic, as many modalities are still being refined.[31] The most common diagnostic test to date has been by RT-PCR, which detects SARS-CoV-2 RNA in clinical samples.[32,33] It is a rapid diagnostic test that can be implemented on a large scale; however, a recent review by Lippi *et al*. found that, mainly due to patients being tested while in the early stages of disease progression (and therefore expressing low viral loads), the RT-PCR test may report false negatives at a rate as high as 30%.[34] Due to this element of uncertainty, it is inadvisable to rely solely on RT-PCR confirmation of COVID-19 when directing the use of PPE.

Safe practices for protecting surgical departments during COVID-19

There is a dearth of primary evidence investigating the education of surgical staff on safe practices to prevent the spread of COVID-19. The importance of timely staff education and training was seen in the 2003 Hong Kong outbreak of SARS, the human coronavirus most closely related to that responsible for COVID-19.[5,35–37] According to recent guidance from the World Health Organization, the most effective preventive measures that surgical staff can take during the COVID-19 pandemic include maintaining at least 1 m of physical distance from others, performing frequent hand hygiene with an alcohol-based hand rub, avoiding touching their eyes, nose and mouth, practising respiratory hygiene, wearing a surgical mask if symptomatic and routinely disinfecting frequently touched surfaces.[15]

In surgical care, a confirmed case of a staff member with COVID-19 could severely compromise, if not paralyse, a department's services for 2 weeks or more. Hence, the number of surgical staff present within a healthcare facility should be minimized wherever possible. Allocating surgical staff to alternating 'teams' for staggered attendance within each department could prevent care from being adversely impacted in such a situation.[38] If any surgical staff member were to display any symptoms suspicious of COVID-19, the staff member and all exposed contacts must self-isolate according to both local and national guidelines.[39]

Where possible, teleconferencing and virtual meetings are practical means to replace in-person meetings.

Identification of vulnerable surgical staff

Multiple large-scale COVID-19 population-based data analyses have highlighted the need to identify vulnerable surgical staff and ensure their safety during the pandemic. Reports from China[8] and Italy[9] have demonstrated that the case-fatality rate amongst COVID-19 patients is significantly greater in those over 70 years of age. Individuals with chronic conditions or those immunocompromised are especially vulnerable.[8] For their own safety, surgical staff within any of these high-risk groups should not be involved in high-risk operations on patients who could potentially transmit the disease, especially those involving aerosol-generating procedures (Table 2).

Table 2 Aerosol-generating procedures (Sources: Australian and New Zealand College of Anaesthetists[40] and Australian Government[41])

Aerosol-generating procedures	• Bag and mask ventilation • Tracheal intubation and extubation • Ventilation via supraglottic airways (including insertion and removal) • Non-invasive ventilation including continuous positive airway pressure and bilevel positive airway pressure • High-flow nasal oxygen therapy • Use of nebulisers • Cardiopulmonary resuscitation • Anaesthesia procedures for women in late first-stage, and second or third stage of labour • Anaesthesia procedures for highly symptomatic patients considered at high risk for aerosol generation (e.g. coughing or other signs of respiratory distress)
High-risk procedural aerosol-generating procedures	• Diagnostic and therapeutic instrumentation of the airway, including bronchoscopy and tracheostomy
High-risk surgical aerosol-generating procedures	• Surgical techniques (e.g. use of pulsed lavage, high-speed drills and laser techniques) involving the upper respiratory tract, such as within ear, nose and throat, maxillofacial, or anterior pituitary operations • Intentional or inadvertent disconnection/reconnection of closed ventilator circuit • Intercostal catheter insertion for relief of pneumothorax • Thoracic surgery entering the lung • Collection of induced sputum

Education for correct 'donning' and 'doffing' of PPE

In order to minimize the spread of COVID-19, formal education and training on proper procedures for donning and doffing PPE must be provided to all surgical staff, regardless of prior experience. Correct donning and doffing of PPE is crucial to ensuring the safety of surgical staff and patients. Deviations from accepted protocols and the practise of improper sequences frequently results in self-contamination[42–44] and can significantly increase the risk of nosocomial SARS-CoV-2 infection. The Australian Commission for Safety and Quality in Healthcare and the Centers for Disease Control and Prevention in the USA are just two of many organizations that have adopted the responsibility of outlining sequences of correctly donning and doffing PPE for non-sterile patient encounters.[45–47]

Table 3 Sequence of donning and doffing personal protective equipment (PPE) for operating on patients with potential COVID-19 infection (Adapted from multiple sources[45–47,49])

Sequence of donning PPE before surgery	Sequence of doffing PPE after surgery
(1) Alert a colleague to supervise entire donning procedure	(1) Alert a colleague to supervise entire doffing procedure
(2) Perform hand hygiene with alcohol-based hand rub	(2) Conduct doffing procedure in anteroom
(3) Don shoe covers	(3) Perform hand hygiene with alcohol-based hand rub over sterile surgical gloves
(4) Perform hand hygiene with alcohol-based hand rub	(4) Doff surgical gown and gloves
(5) Don P2/N95 respirator that has been previously fit-tested	(5) Perform hand hygiene with alcohol-based hand rub
(6) Perform fit check of P2/N95 respirator	(6) Doff face and eye protection
(7) Don bouffant hat	(7) Perform hand hygiene with alcohol-based hand rub
(8) Don face and eye protection	(8) Doff bouffant hat
(9) Perform surgical scrub	(9) Perform hand hygiene with alcohol-based hand rub
(10) Don sterile, fluid-impervious, long-sleeved surgical gown	(10) Doff P2/N95 respirator
(11) Don two pairs of sterile surgical gloves	(11) Perform hand hygiene with alcohol-based hand rub
	(12) Exit anteroom
	(13) If possible, shower and change into new scrubs prior to resuming clinical duties[50]

Donning and doffing of PPE before and after operating on potential COVID-19-positive patients

High-risk situations where full PPE is required for surgery due to potential COVID-19 exposure, are outlined in Table 2. Donning and doffing of PPE must be carried out in a controlled and methodical fashion, especially during surgical emergencies where the risks of contamination and infection of surgical staff are greater.[48] There are currently no peer-reviewed publications that outline a validated sequence of donning and doffing PPE specifically for surgery on patients who are potentially COVID-19 positive.

Table 3 outlines a sequence of donning and doffing PPE for performing sterile surgical procedures on patients with potential COVID-19 infection, which has been adapted from multiple sources.[45–47,49] This may be modified to suit the protocols of individual healthcare facilities. Ideally, another trained staff member should supervise the entire donning and doffing procedure to ensure that each step is carried out correctly.[42,51]

Aerosol-generating procedures

The possible exposure to SARS-CoV-2 viral particles during aerosol-generating procedures is a potential risk to surgical staff. During the current pandemic, surgical and perioperative medical colleges, societies and associations have provided guidance on potential aerosol-generating procedures (including those within surgical operations), for example, the recent statement from the Australian and New Zealand College of Anaesthetists (Table 2).[40]

Surgical masks

Standard surgical masks are loose-fitting, single-use items that cover the nose and mouth. They are used as part of standard droplet-infection precautions to protect against splashes and sprays, including the respiratory secretions of patients.

There are three levels of barrier protection provided by surgical masks, which can be utilized depending on the situational risk of exposure to droplets and biological material.[52] However, standard surgical masks do not provide a seal around the face and thus are inferior to FFRs in protecting against airborne respiratory infections. This has been demonstrated in multiple randomized controlled trials of large sample size.[53–55] Given that SARS-CoV-2 is viable in aerosols,[5] standard surgical masks do not provide adequate protection for COVID-19. However, surgical masks offer a degree of infection control barrier when worn by coughing patients, they can limit the potential dissemination of infectious respiratory secretions.[46,56] Such use can be advocated when transporting surgical patients to and from the operating theatre as a method of infection control.[57]

Surgical P2 and N95 FFRs

Evidence validating the use of surgical P2/N95 respirators is dominated by small, laboratory-based studies. However, because standard surgical masks fail to provide adequate protection for the aerosol transmission of SARS-CoV-2, surgical P2/N95 respirators protecting against viral particles should be used.[15] A good facial fit that minimizes aerosol contact with the mucous membranes of the nose and mouth is the key to their design and use. These respirators consist of four to five layers of material, providing filtration through both mechanical impaction and electrostatic capture.[46] They can be used as part of airborne precautions during COVID-19.

While the terms 'P2 respirator' and 'N95 respirator' are often used interchangeably in the healthcare setting, they are required to meet different national standards. In Australia and New Zealand, the requirements for P2 respirators (Australian/New Zealand Standards 1716: 2012[58] and 1715: 2009[59]) include a filter efficiency of at least 94% in standardized testing with a sodium chloride aerosol at a flow rate of 95 L/min.[46] The National Institute for Occupational Safety and Health in the USA sets the standards for N95 respirators,[60] which require a filter efficiency of at least 95% in standardized testing with a sodium chloride aerosol at a flow rate of 85 L/min.[46,61]

As most particle penetration of P2/N95 respirators occurs through face-seal leakage,[62] optimizing facial fit through comprehensive fit-testing and fit-checking is essential to ensure adequate protection against airborne transmission[63,64] of SARS-CoV-2. Fit checks must be performed at every instance of donning to ensure the respirator is properly applied.[46] It is also recommended that all members of surgical staff are clean-shaven, if possible, to ensure optimal facial seal and fit.[65]

Extending the use of P2 and N95 respirators

At the time of publication, there is a worldwide shortage in the supply of PPE relative to the demand created by the COVID-19 global

pandemic.[15,66,67] This is especially true for FFRs. Options for safely extending their use must be considered, however, scientific studies investigating these methods have been small and laboratory-based.

Using a full-face shield over a surgical P2/N95 respirator protects it from droplets and aerosols, which may allow its extended use.[68] Similarly, covering respirators with standard surgical masks or similar disposable covers can potentially extend the life of the respirator without significant adverse effects on the cardiorespiratory physiology of the wearer.[69] Laboratory-based studies on the disinfection of surgical P2/N95 respirators by ultraviolet germicidal irradiation are promising and may be a potential option to allow safe re-use.[70] This is particularly encouraging for the COVID-19 pandemic, since the ultraviolet dose required to inactivate single-stranded RNA viruses such as SARS-CoV-2 is relatively low.[71]

Conclusions

In the fight against COVID-19, it is essential to supplement standard infection control measures with the appropriate use of PPE, especially where there are risks of potential exposure to any biohazardous material. Surgical departments must ensure that their staff receive formal training in the correct use of PPE. Donning and doffing must always be methodical and supervised by another staff member, especially during surgical emergencies and aerosol-generating procedures. Standard surgical masks fail to protect against the airborne transmission of SARS-CoV-2, so properly fit-tested and fit-checked surgical P2/N95 respirators are a necessary PPE item for surgical staff. Where possible, patients with severe respiratory symptoms and those with suspected or confirmed COVID-19 should wear surgical masks during transfer to and from the operating theatre. Potential solutions have been published in the peer-reviewed literature to enable the extended use of surgical P2/N95 respirators in situations of limited supply.

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Conflicts of interest

None declared.

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