NARRATIVE REVIEW ARTICLE

Perioperative Considerations for Tracheostomies in the Era of COVID-19

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The morbidity, mortality, and blistering pace of transmission of infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has led to an unprecedented worldwide health crisis. Coronavirus disease 2019 (COVID-19), the disease produced by SARS-CoV-2 infection, is remarkable for persistent, severe respiratory failure requiring mechanical ventilation that places considerable strain on critical care resources. Because recovery from COVID-19–associated respiratory failure can be prolonged, tracheostomy may facilitate patient management and optimize the use of mechanical ventilators. Several important considerations apply to plan tracheostomies for COVID-19–infected patients. After performing a literature review of tracheostomies during the severe acute respiratory syndrome (SARS) and Middle East Respiratory Syndrome (MERS) outbreaks, we synthesized important learning points from these experiences and suggested an approach for perioperative teams involved in these procedures during the COVID-19 pandemic. Multidisciplinary teams should be involved in decisions regarding timing and appropriateness of the procedure. As the theoretical risk of disease transmission is increased during aerosol-generating procedures (AGPs), stringent infectious precautions are warranted. Personal protective equipment (PPE) should be available and worn by all personnel present during tracheostomy. The number of people in the room should be limited to those absolutely necessary. Using the most experienced available operators will minimize the total time that staff is exposed to an infectious aerosolized environment. An approach that secures the airway in the safest and quickest manner will minimize the time any part of the airway is open to the environment. Deep neuromuscular blockade (train-of-four ratio = 0) will facilitate surgical exposure and prevent aerosolization due to patient movement or coughing. For percutaneous tracheostomies, the bronchoscopist should be able to reintubate if needed. Closed-loop communication must occur at all times among members of the team. If possible, after tracheostomy is performed, waiting until the patient is virus-free before changing the cannula or downsizing may reduce the chances of health care worker infection. Tracheostomies in COVID-19 patients present themselves as extremely high risk for all members of the procedural team. To mitigate risk, systematic meticulous planning of each procedural step is warranted along with strict adherence to local/institutional protocols. (Anesth Analg 2020;131:378–86)

GLOSSARY

AGPs = aerosol-generating procedures; **BiPAP** = bilevel positive airway pressure; **CDC** = Centers for Disease Control and Prevention; **COVID-19** = coronavirus disease 2019; **CPAP** = continuous positive airway pressure; **ETT** = endotracheal tube; **F_{IO_2}** = fraction of inspired oxygen; **HCWs** = health care workers; **HEPA** = high-efficiency particulate air; **ICU** = intensive care unit; **INR** = international normalized ratio; **MERS** = Middle East Respiratory Syndrome; **OR** = operating room; **Pa_{O_2}** = partial pressure of oxygen; **PAPRs** = powered air-purifying respirators; **PCR** = polymerase chain reaction; **PEEP** = positive end-expiratory pressure; **PPE** = personal protective equipment; **SARS** = severe acute respiratory syndrome; **SARS-CoV-2** = severe acute respiratory syndrome coronavirus 2; **VTE** = venous thromboembolism; **WHO** = World Health Organization

Coronavirus infections in humans can vary from mild diseases, such as the common cold, to severe end-organ dysfunction such as acute respiratory distress syndrome.[1] The morbidity, mortality, and blistering pace of transmission, of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)

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since December 2019 has led to an unprecedented worldwide health crisis and been declared a pandemic by the World Health Organization (WHO). As of May 15, 2020, there have been over 4.5 million confirmed cases around the world.[2]

The severity and duration of respiratory failure due to coronavirus disease 2019 (COVID-19) has led to concern regarding potential shortages of medical resources. As of May 12, 2020, the Institute for Health Metrics and Evaluation at the University of Washington projected a need for 15,739 intensive care unit (ICU) beds in the United States.[3,4] Moreover, early reports show that median duration of mechanical ventilation for patients with COVID-19 is approximately 11 days and a recent analysis in a large urban setting has reported a median duration of mechanical ventilation of 16 days, and median ICU length of stay of 17.5 days.[5,6]

Patients requiring prolonged mechanical ventilation are often offered tracheostomy to reduce the need for sedation and aid ventilatory weaning after endotracheal intubation. Other potential advantages of tracheostomy include increased mobility and improved respiratory toilet.[7–10] Few data are available to guide the timing and preferred procedural approach for patients with SARS or COVID-19, and indeed evidence outside of this condition also suggests variation in practice regarding optimal timing of tracheostomy.[11] Although systematic analysis from the SARS outbreak is lacking, several reports describe open surgical tracheostomies being safely performed on infected patients.[12,13]

Important considerations apply to planning and conducting tracheostomies for COVID-19–infected patients, primarily because of the periprocedural risks associated with generation of aerosols. A literature review of tracheostomies during the SARS and Middle East Respiratory Syndrome (MERS) outbreaks was performed using PubMed terms (Tracheostomy OR tracheotomy) AND (Severe Acute Respiratory Syndrome OR SARS OR Middle East Respiratory Syndrome OR MERS). The search resulted in 111 total articles. Five publications were reviewed (3 case series and 2 case reports), all describing tracheostomy experience in patients with SARS.[12–16] There were no publications of tracheostomy in patients with MERS. The current review synthesizes important learning points from these experiences and best practice for perioperative teams involved in tracheostomies during the COVID-19 pandemic.

INFECTION CONTROL

Risk of SARS-CoV-2 Transmission

Our understanding of coronavirus transmission risk remains incomplete. Pathogen transmission is thought to occur mainly via inhalation of respiratory droplets containing virus, resembling the spread of influenza. With droplet transmission, virus released in the respiratory secretions when a person with infection coughs, sneezes, or talks can infect another person on contacting mucous membranes. Infection can also occur if a person touches an infected surface and then touches his or her eyes, nose, or mouth. Although SARS and COVID-19 are both transmitted by droplets, COVID-19 has higher infectivity than SARS, with an estimated R_0 of approximately 2.2 and significant asymptomatic carrier transmission.[17,18] Health care workers (HCWs) working closely with these patients are at a higher risk of coronavirus infection. During the SARS epidemic, of the 1755 patients in Hong Kong, over 400 were HCWs.[14] Furthermore, during the SARS outbreak at Sunnybrook and Women's College Health Sciences Centre, in Toronto, 9 HCWs were infected when involved in a difficult airway situation.[19] The experience during the current pandemic has been similar. Reports from China and Italy indicate that thousands of health care personnel acquired COVID-19.[20,21] In the United States, a report from the Centers for Disease Control and Prevention (CDC) indicates that over 9000 HCWs have already been infected with COVID-19.[22] Several guidelines have recommended best practices and ensure adequate protection of HCWs.[23–25]

Aerosol-Generating Procedures

Given the current uncertainty regarding transmission mechanisms, airborne precautions are recommended in high-risk situations such as aerosol-generating procedures (AGPs). In AGPs, there is formation of a gas cloud that entrains ambient air propelling pathogen-bearing droplets much farther than if they were emitted in isolation.[26–28] AGPs include cardiopulmonary resuscitation, noninvasive positive pressure ventilation (bilevel positive airway pressure [BiPAP] and continuous positive airway pressure [CPAP]), disconnection of the patient from the ventilator during invasive mechanical ventilation, endotracheal intubation, endotracheal tube (ETT) advancement or exchange, airway suctioning, high-frequency oscillatory ventilation, tracheostomy, chest physiotherapy, nebulizer treatment, sputum induction, and bronchoscopy.[29] For HCWs performing AGPs on patients with COVID-19, the Surviving Sepsis Campaign recommend the use of fitted respirator masks (N95, FF2, or equivalent) in addition to other personal protective equipment (PPE), such as gloves, gown, and eye protection.[23] When possible, AGPs on ICU patients with COVID-19 should be performed in a negative-pressure room to limit the spread of virus outside the room.[23]

Table. General Recommendations for Tracheostomy in COVID-19 Patients

Personal protective equipment	Fitted respiratory mask, surgical cap, impermeable gown, shoe covers, goggles, and full-face shields.
Staff and personnel	Minimize number of people in the room to 3 (2 procedural staff and anesthesiologist). Nurse, respiratory therapist, and additional anesthesiologist standing right outside of the room and immediately available to help, if needed.
Timing of procedure	Preferably between ventilator days 14–21 when viral load is expected to be decreasing. Consider repeat testing to assess vital clearance.
Surgical considerations	Proficient operators should be involved. Minimize the time that airway is open to the environment and allow apnea before securing the airway, if tolerated.
Anesthetic considerations	Deep neuromuscular blockade should be instituted. Avoid circuit disconnection as much as possible.
Ventilatory support	Patient must be able to tolerate periods of apnea as necessary for safe conduct of the procedure. Cut-offs of $Pao_2 \geq 60$ mm Hg on $Fio_2 \leq 50\%$ and PEEP ≤10 cm H_2O are suggested.
Management of anticoagulation	Decision regarding when to stop heparin infusions before procedure should be left at discretion of the team. We recommend stopping at least 2–4 h before procedure, a platelet count >50,000/μL, and INR <1.5.
Choice of approach (open versus percutaneous)	Prioritize route that secures the airway in the safest and quickest manner. In percutaneous approach, bronchoscopist needs to be capable of managing airway.
Postprocedure waste disposal	Whenever possible, disposable equipment should be used. The presence of observer supervising doffing is encouraged, to decrease self-contamination.
Posttracheostomy care	Avoid tracheostomy changes, downsizing, or decannulation until infection clearance has been achieved.

Abbreviations: COVID-19, coronavirus disease 2019; Fio_2, fraction of inspired oxygen; INR, international normalized ratio; Pao_2, partial pressure of oxygen; PEEP, positive end-expiratory pressure.

PERIOPERATIVE CONSIDERATIONS FOR TRACHEOSTOMY PROCEDURES

General Considerations

Tracheostomy (open or percutaneous) and bronchoscopy are AGPs that may risk exposing HCWs to virions suspended in aerosolized particles. Many tracheostomies performed in the ICU are semielective and can safely be delayed. The nature of respiratory failure in COVID-19 patients is such that it may often require prolonged mechanical ventilation. In the setting of limited ICU beds, ventilators, and increasing shortages of sedative drugs—earlier tracheostomy—may become medically more appropriate as the best form of continuation of care. The care team should aim for performing the procedure at a time that minimizes risk to the staff involved while not compromising best practices in patient care.

Institutional Experience

As of May 1, 2020, we have safely performed more than 15 tracheostomies in COVID-19 patients, using open, percutaneous, and modified-percutaneous techniques. Procedures have been performed by an interventional pulmonary/thoracic surgery, otolaryngology/head and neck surgery, or general surgery team accompanied by an anesthesiologist and in occasionally a respiratory therapist. To standardize this high-risk procedure, guidelines for safe perioperative management of tracheostomies were developed via multidisciplinary discussions between anesthesia, critical care, and procedural teams. Simulation and team training sessions were run for involved personnel to become familiar with the modified workflows before the first tracheostomy. The following recommendations are summarized in the Table.

Personal Protective Equipment

PPE, defined as is strongly recommended for all personnel present during tracheostomy. The ability of PPE to reduce disease transmission is supported by a case series of 15 surgical tracheostomies in SARS-related patients performed during the SARS epidemic with no transmission despite 124 HCW having had direct contact with these patients.[12] Every provider in the room should wear a fitted respirator mask, surgical cap, impermeable gown, shoe covers, gloves, goggles, and full-face shields, or as guided by local/institutional protocols. Special attention to the neck area is needed, as it may be left exposed by standard PPE.[30] In this case, a face shield which is long enough to protect the neck may be used or staff may opt for an additional element of PPE to cover the neck. Compelling evidence regarding optimal coverage is lacking, and surface coverage area, barrier material, comfort, ease of donning and doffing are all relevant factors in PPE appropriateness.[31]

Although N95 may provide similar protection, some institutions have required the use of powered air-purifying respirators (PAPRs) for all providers performing AGPs.[31] Following proper donning and doffing procedures with PPE is important to reducing infection. Team members should have undergone training protocols before performing their roles during AGPs. In the absence of specific institutional guidance, both CDC and/or professional society recommendations are available.[32] Thorough hand hygiene, including cleansing of any exposed skin surfaces, should be practiced before and after the procedure. Procedures should preferably be performed in negative-pressure rooms, ideally with adjacent anterooms, to minimize escape of aerosolized viral particles. When negative-pressure rooms are not available, we recommend that procedures take place in rooms

with high-efficiency particulate air (HEPA) filters. At our institution, we use HEPA filters beginning 30 minutes before the procedure and continuing for at least 30 minutes afterward to ensure safety of staff and clearance of virus.

Transport to the operating room (OR) represents additional risk of exposure to other hospital staff, and the risk-benefit ratio of patient transport should be carefully weighed in each clinical scenario. During the high volume of critically ill patients, many institutions have had to adapt non-ICU locations to accommodate these patients (so-called surge units). The "surge units" are often open, with no isolation or physical barrier between patients. In this case, it may be prudent to perform the procedure in the OR to avoid higher exposure risk to additional staff not directly involved with the procedure. When the procedure is performed in the OR, patients should be transported directly to the room, bypassing the holding area. Similar considerations apply postprocedure and patients should be transported straight from the OR back to a negative-pressure room. HCWs in direct contact with the patient should avoid touching environmental surfaces (eg, elevator buttons) during transport. Although a negative-pressure room in the ICUs is preferred for performance of these procedures, logistic considerations may preclude this option. If such a circumstance may arise, we use a HEPA filter as described above.

Staff and Personnel

All planned tracheostomy cases on patients with COVID-19 should be preceded by a multidisciplinary discussion, including the procedural service, critical care, anesthesia, infectious diseases, respiratory therapy, and nursing teams. This discussion should include appropriateness, risk assessment, and optimal timing. Preprocedure huddles, design, and practice of high-fidelity simulation sessions with different patient scenarios are highly encouraged. To minimize staff exposure during the procedure, the number of people in the room should be limited to those absolute necessary. Open tracheostomies can safely be performed with 3 people in the room (2 procedural staff and anesthesiologist). The same number (proceduralist, anesthesiologist, and bronchoscopist) is required for a percutaneous approach. The ICU nurse caring for the patient, respiratory therapist, and additional member of anesthesia team should remain outside of the room, immediately available to help, and provide ancillary support as needed. To minimize the number of people in the room and ensure patient safety and clear communication, we have been using a communication system consisting of headphones with mouth pieces (C-COM Pro, Carrot Medical, Bothell, WA) which are worn by personnel inside (2 proceduralists and anesthesiologist) and outside (nurse and respiratory therapist) the room. Infusion pumps are left outside of the room and the anesthesiologist and nurse can communicate efficiently to make prompt changes in medication dosages as required.

Timing of Procedure

Conflicting data regarding optimal indications and timing for tracheostomy in COVID-19 have resulted in wide practice variability.[33–36] For patients who are being kept on mechanical ventilation due to inability to protect their airway, manage secretions, or poor mental status but do not require ventilator support otherwise, we recommend that the procedure is performed between ventilator days 14–21. Frequent pronation, supination, risk of ETT migration, copious secretions associated with plugging, and pronounced laryngeal edema associated with COVID-19 can be difficult with an ETT instead of a tracheostomy. In addition, prolonged ventilation times for COVID-19 patients may consume ICU beds and ventilators. Under such circumstances, early tracheostomy may liberate patients from the ventilator and facilitate transfer out of the ICU to a lower level of care. On the other hand, a 2013 study reports that fewer patients underwent tracheostomies when a late strategy was applied.[37] A late strategy may ultimately reduce the need for the procedure.

In some cases, prolonged ventilator weaning of COVID-19 patients may nullify the ability reduce ICU patient census. The vast majority of patients with COVID-19 achieve seroconversion by day 14, with a slow but steady decline of respiratory viral load.[37] Although viral shedding from nasopharyngeal aspirates may occur up to 24 days after symptom onset, viral loads are significantly lower 14 days after presentation.[38–40] It is probable, although not confirmed, that transmission may be more likely in earlier stages of infection. If so, performing the procedure after 2 weeks might pose less risk to the staff involved. This window may be revised as more tests to assess seroconversion become available. If patient transfer to a lower level of care is not a priority, ensuring seroconversion or negative polymerase chain reaction (PCR) testing before performing the procedure is a reasonable step to protect personnel. Although testing can be performed for infectious risk stratification, factors such as a patient's transmissibility of the infection should be weighed against the need for the procedure and benefits achieved with it at a given time.

INTRAOPERATIVE IMPLICATIONS

Surgical

To minimize the total time that staff is exposed to an infectious aerosolized environment, tracheostomy should be performed by the most experienced available operators. If an indication for gastrostomy tube

placement is present, performing both procedures concurrently may avoid subsequent exposure of another procedure team. The surgical team should be mindful that suctioning is aerosol-generating and its use must be minimized. If suction is used, a closed system should be used with a viral filter.

Several different techniques have been described. Similar principles apply for both open and percutaneous tracheostomies:

- Most proficient available operators should be involved.
- Minimize the time any part of the airway is open to the environment.
- Before performing tracheotomy or serial dilation, advancement of the ETT to the distal trachea just above the carina may minimize aerosolization.
- If clinical characteristics of patient allow, apnea should be attempted as much as possible, ideally from introduction of bronchoscope or opening of the trachea, until tracheostomy is placed and cuff inflated, and closed ventilator circuit attached. Having a syringe attached to the pilot balloon of the tracheostomy tube is recommended to allow for immediate balloon inflation once inserted.
- Before disconnecting the ventilator circuit, ETT should be clamped.
- Closed-loop communication between the team members should be maintained throughout the procedure.

Anesthetic

Deep neuromuscular blockade (train-of-four ratio equal 0) is highly recommended to facilitate surgical exposure and prevent patient movement or coughing, which may prolong operative time and increase the risk of pathogen exposure. A viral filter should be placed on the endotracheal and tracheostomy tubes to prevent shedding of the virus in the event of ventilator disconnection. Circuit disconnection should occur distal to the filter, if necessary. If possible, mechanical ventilation should be interrupted just before entering the trachea via tracheotomy to reduce aerosolization of secretions. In percutaneous approaches, ventilation should also be interrupted, if possible, during tracheal dilation. After insertion of the tracheostomy cannula, the anesthesiologist must verify that the cuff is inflated before recommencing ventilation.

Ventilatory Support

Patients must ideally be medically stable to undergo tracheostomy, with resolution of severe hypoxemia. When deciding whether a specific patient is clinically stable to undergo the procedure, it is important to have a multidisciplinary discussion and take into account not only mechanical ventilation settings, but also patient-related factors (eg, anatomy, presence of neck scar, radiation, body habitus) that may render the procedure more challenging. To protect staff and minimize exposure, more procedural apnea time is possibly expected in patients with COVID-19, in comparison to other patients. Hence, the surgical and anesthesia teams should be reasonably confident that the patient would be able to tolerate periods of apnea as necessary for safe conduct of the procedure. At our institution, we established minimal cut-offs of partial pressure of oxygen (Pao_2) ≥60 mm Hg on fraction of inspired oxygen (Fio_2) ≤50% and positive end-expiratory pressure (PEEP) ≤10 cm H_2O to consider the patient a safe candidate for the procedure. However, decisions should be made on a case-by-case basis by a multidisciplinary team.

Management of Anticoagulation

Individuals with COVID-19 may have a number of coagulation abnormalities leading to a hypercoagulable state.[41–44] The pathogenesis of hypercoagulability in COVID-19 is incompletely understood, but likely involves a combination of complement-mediated endothelial injury, blood stasis (especially in hospitalized critically ill patients), and changes in circulating prothrombotic factors.[41,42,45] Observational studies have also reported an increased risk of venous thromboembolism (VTE) in these patients as well as large-vessel stroke in patients with no significant risk factors.[46–54] Moreover, autopsy studies in individuals who have died from COVID-19 have demonstrated microvascular thrombosis in the lungs.[44,45,53]

This prothrombotic state appears to adversely affect outcomes in these patients.[54] Despite the lack of high-quality studies supporting therapeutic anticoagulation in patients with coronavirus pneumonia, emerging observational data may indicate a possible survival benefit.[55,56] Several institutions across the world have instituted aggressive protocols with full-dose anticoagulation of critically ill patients with COVID-19.

Such anticoagulation protocols present a challenge in patients undergoing tracheostomy. Studies have found that tracheostomies might be safely performed while on therapeutic anticoagulation, but considerable practice variability exists.[57–59] While full-dose anticoagulation might not, when discontinued appropriately before procedure, predispose patients to bleeding, when bleeding occurs, it appears to be associated with significant events.[60] At our institution, we usually stop heparin infusions between 2 and 4 hours before the procedure and have not had any bleeding complications to date. Heparin infusion is typically restarted within 2 hours after procedure depending on the intraoperative course and proceduralist's preference. We also recommend a platelet

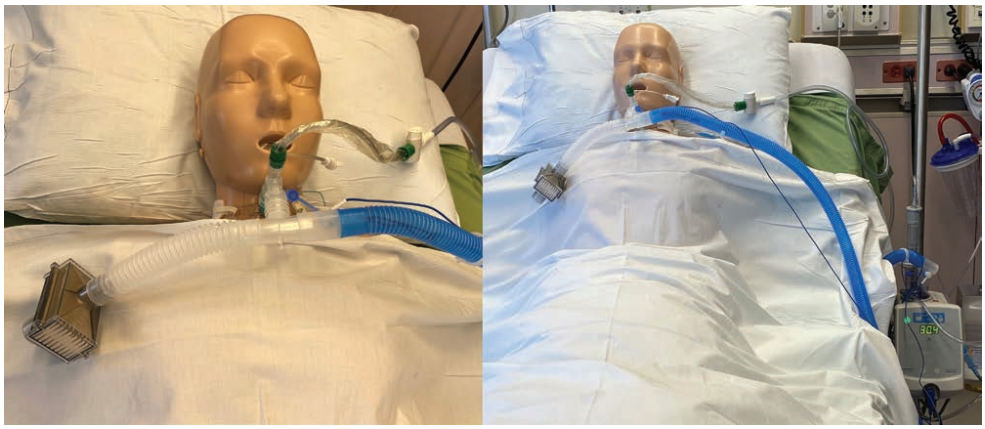

Figure. Adapted T-Piece system with viral filter in expiratory limb for use in tracheostomy patients liberated from mechanical ventilation.

count >50,000/μL and international normalized ratio (INR) <1.5.

Choice of Approach (Open Versus Percutaneous)

The choice of approach should be made by the procedural staff as each has its advantages and disadvantages. We recommend that the route that secures the airway in the safest and quickest manner is chosen and this should remain at the discretion of the proceduralist. No evidence supports the superiority of percutaneous versus open tracheostomy. Percutaneous tracheostomies are more often performed at the bedside but can be challenging in some patient populations, such as morbidly obese patients with large neck circumference. If strict infectious precautions are followed, an open approach can be safely conducted.

For percutaneous tracheostomies, the bronchoscopist should be capable of reestablishing airway access (with laryngoscopy and endotracheal intubation), if necessary. After tracheostomy placement and confirmation with end-tidal carbon dioxide, fiberoptic bronchoscopy must be performed to confirm appropriate positioning. This procedure should be performed under apnea, if tolerated. A modified-percutaneous approach has also been performed at our institution. During this approach, the ETT is advanced distally near the carina and cuff is left inflated. The bronchoscope is then inserted along the side of the ETT (instead of within the ETT normally used in a conventional approach) to minimize aerosolization and guide percutaneous puncture of the trachea.

Postprocedural Debrief

We recommend a postprocedural debriefing among members of the procedural team to discuss the processes, obtain real-time feedback, and therefore streamline workflows for future cases.

Postprocedure Waste Disposal

After completion of the procedure, careful attention must be paid to waste disposal and decontamination of equipment. Whenever possible, disposable equipment should be used. Staff handling decontamination of surgical equipment should wear adequate PPE. HCWs should be aware of risk of self-contamination during doffing of PPE, which was reported during the recent Ebola epidemic.[61,62] To minimize these risks, strict adherence to standard operating procedure is needed. The presence of a trained observer supervising each step of doffing is highly encouraged to improve compliance.

Posttracheostomy Care

We recommend that the following supply be left at the bedside of COVID-19 patients who have undergone tracheostomy: manual bag ventilator with viral filter, suction equipment (gauge, canister/tubing, appropriate suction catheters), spare inner cannula, spare tracheostomy tube, plus spare tracheostomy tube that is one size smaller. When the patient is ready to be liberated from the ventilator, a T-piece system with a viral filter on the expiratory end, and inline suction catheter may be used. Particular attention should be given to the extra weight and tension on the tracheostomy site[63] (Figure).

Tracheostomy collar trials should ideally be done in a negative-pressure isolation room. When such room is unavailable, a portable HEPA filter can be used to minimize environmental contamination. Placing a surgical mask over the tracheostomy site may also limit droplet spread. Patients who are stably breathing on a tracheostomy mask can undergo speaking valve trials. It is important to remember that placement of the speaking valve and capping should be considered AGPs, so airborne precautions are warranted. However, once the tracheostomy is capped, airborne precautions are not necessary and patients may wear a facemask.

If possible, we recommend refraining from tracheostomy changes, downsizing or decannulation until COVID-19 infection has cleared. In the event of an

emergency, when tube exchange is clinically indicated (malposition, cuff rupture), all precautions mandated for the original procedure apply.

CONCLUSIONS

As the SARS-CoV-2 pandemic progresses, we expect health care systems across the globe to be severely strained, taking a toll on the health care workforce and patients alike. Tracheostomies in COVID-19 patients present themselves as extremely high-risk procedures for all members of the procedural team. Systematic meticulous planning of each procedural step is warranted along with strict adherence to local/institutional protocols to mitigate risk to procedural members. ■

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