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## Methods for a Seamless Transition from Tracheostomy to Spontaneous Breathing in COVID-19 Patients.

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**Methods for a Seamless Transition from Tracheostomy to Spontaneous Breathing in COVID-19 Patients.**

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### **Abstract**

The COVID-19 pandemic has profoundly impacted healthcare delivery worldwide. A small, yet significant number of patients with respiratory failure will require prolonged mechanical ventilation while recovering from the viral-induced injury. The majority of reports thus far have focused on the epidemiology, clinical factors, and acute care of these patients, with less attention given to the recovery phase and care of those patients requiring extended time on mechanical ventilation. In this monograph, we review the procedures and methods to safely care for COVID-19 patients who require tracheostomy, gastrostomy, weaning from mechanical ventilation, and final decannulation. The guiding principles consist of modifications in the methods of airway care, to safely prevent iatrogenesis and promote safety in patients severely affected by COVID-19, including mitigation of aerosol generation to minimize risk for healthcare workers.

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### Introduction

The current coronavirus disease 2019 (COVID-19) pandemic has disrupted the world's health care systems. While the majority of reports have focused on the epidemiology, clinical course and acute care of these patients, less attention has been given to their management during recovery from the acute injury<sup>1-3</sup>. A recent report highlighted the importance of post-acute care facilities and noted an urgent need to adjust the capability of these facilities to serve as effective "pop-off valves" to assist survivors of severe COVID-19<sup>4</sup>.

It is estimated that up to 5% of patients infected by the virus require mechanical ventilation. The natural course of these patients is still not well established, although data from several studies suggest a relatively prolonged time on mechanical ventilation. A review of patients from Wuhan, China showed that out of 37 patients with Acute Respiratory Distress Syndrome (ARDS), 20 were alive at 28 days requiring some form of supported ventilation<sup>5</sup>. In a series of 21 critically ill patients with COVID-19 in Washington state, 71% required mechanical ventilation. At day 25, 38% continued to require this therapy<sup>3</sup>. Finally, most patients requiring mechanical ventilation suffer from multiple comorbidities and are frail, likely requiring prolonged recovery time. These data highlight the prolonged nature of respiratory failure in critically ill patients with COVID-19 and the need for a longer-term care plan transition.

Mechanical ventilation has greatly impacted the overall mortality of critically ill patients with respiratory failure from COVID-19 infection. However, there are new challenges posed by the increasing numbers of survivors of the acute phase now requiring prolonged care. For example, the timing or technique to perform tracheostomies in these patients is not clear. Even less is

known about the practical modifications needed to safely care for patients with a tracheostomy tube as they continue the journey towards liberation from mechanical ventilation, while simultaneously minimizing the risk of exposure to healthcare personnel (HCP). Historically, the care is often fragmented, as the physicians performing the tracheostomy are typically not the same as those faced with the process of weaning from mechanical ventilation and ultimate decannulation as well as the rehabilitation process leading to full recovery. The COVID-19 pandemic presents a unique challenge to HCP, as the virus is highly contagious. These professionals work in close proximity to patients for prolonged periods of time, perform high-risk aerosol generating procedures (AGP), and may have suboptimal personal protective equipment (PPE)<sup>6-8</sup>. Currently, there is no targeted treatment for COVID-19, therefore efforts must be focused on prevention while we wait outcomes of the trials currently under study as well as the development of an effective vaccine. How long patients remain contagious after clinical recovery remains uncertain, thus testing guidelines may need to be revised as additional information becomes available.

In response to these uncertainties, we convened a working group of experts with experience across the continuum of care, from intensive care units to long term care facilities with three goals in mind. First, provide guidance on tracheostomy and gastrostomy tubes and their long-term management in COVID-19 patients surviving mechanical ventilation. Second, to provide recommendations and modifications of standard practices, in order to minimize exposure to aerosols, which can then be implemented in care bundles for tracheostomy teams. Third, to serve as a resource to achieve a seamless transition from the ICU stay to recovery in patients afflicted by COVID 19 requiring prolonged mechanical ventilation.



### Methodology

The working group was formed after identifying experts with experience in the areas of tracheostomy and percutaneous endoscopic gastrostomy (PEG) tube placement as well as the management of long-term mechanical ventilation/tracheostomy and weaning. The five experts included were; EF and CO, who are Interventional Pulmonologists, MP who is an Advanced Bronchoscopist, BC and MD who are pulmonologist with extensive experience in long-term ventilatory management, weaning and tracheostomy weaning/decannulation. Their conflict of interests are listed with this publication. The group performed a review of the available literature from the COVID-19 pandemic as well as prior pandemics using the strategy outlined below. First, we searched for published societies guidelines addressing tracheostomy tube and PEG tube placement and management of prolonged mechanical ventilation in COVID-19 patients. Specifically, we searched the following sites; Center for Disease Control and Prevention (CDC), American Association for Respiratory Care (AARC), American Thoracic Society (ATS), American College of Chest Physician (ACCP), the American Academy of Otolaryngology-Head and Neck Surgery, The Society of Thoracic Surgeons, The European Respiratory Society, and The Society for Advanced Bronchoscopy. We also searched web pages for any published guidelines on the topic as of April 20th 2020. Secondly, we searched in Medline (Pubmed) and Google Scholar for primary literature addressing the key points of this review: Viral transmission, aerosol generating procedures, tracheostomy and PEG placement (technique, timing), personal protective equipment (PPE) for airborne pathogens, and epidemiologic reports addressing superspreading events (SSE). For the creation of table 1 we extracted product's specifications from manufacturers of tracheostomy tubes. From these searches, a total of 107 articles were extracted, discussed by all authors in an iterative process. The final

recommendations are the results of distilling the information obtained from the above process and the group's firsthand experience.

### **Tracheostomy**

#### *Rationale for the procedure*

Placement of a tracheostomy tube in patients with prolonged respiratory failure has shown advantages including; reduced work of breathing, improved secretion management, patient comfort, enhanced communication, and reduced need for sedation and paralytics<sup>9, 10</sup>, the latter two been linked to serious long-term weakness and delirium<sup>11</sup>. Tracheostomies also help facilitate the shift to less intensive care areas of the hospitals or to rehabilitation facilities that specialize in the long-term management of these patients. For patients failing spontaneous breathing trials or extubation efforts, well timed tracheostomies decrease the use of scarce resources such as intravenous sedatives, neuromuscular blockers, and intensive care unit (ICU) beds. This is particularly important during the COVID-19 pandemic as many healthcare systems have been overwhelmed by these patients and have been forced to transform multiple care areas into distinct COVID-19 units, often cannibalizing the functional capacity of other important areas of the hospitals.

Advanced planning is paramount as post-tracheostomy care also requires detailed protocols to minimize AGP and maximize HCP safety. In the COVID-19 era, initial decisions may have secondary effects that places other downstream healthcare workers at increased risk unnecessarily (Figure 1 Panel A). The care of these patients therefore should be a joint effort between pre- and post-tracheostomy practitioners. The creation of a multidisciplinary tracheostomy team and the use of care bundles has been shown to decrease the time to

decannulation and improve patient satisfaction<sup>12-14</sup>. A practical example of one such bundle is provided in Table E1 of the online supplement.

### *Timing*

In the current COVID-19 pandemic there is limited high-quality data to guide us on the optimal timing of tracheostomy. In reaction to this pandemic, most society guidelines recommended avoiding tracheostomy placement due to the risks to HCP or waiting at least 2-3 weeks after intubation and preferably until COVID-19 testing is negative<sup>15</sup>.

While agreeing with the concern for risks to HCPs, we feel that these opinion-based guidelines are overly conservative. They do not consider the risks of prolonged intubation and resource utilization from delaying tracheostomy placement. Furthermore, these guidelines do not reflect the limited value of a negative nasopharyngeal COVID-19 swab as viral replication and shedding may persist in the distal airways and parenchyma<sup>16, 17</sup>.

A recent publication from New York described their experience with a modified technique used in 98 patients. Their average timing for tracheostomy was 10.6 +/-5 days of mechanical ventilation prior to tracheostomy placement. Importantly, none of the healthcare providers developed symptoms or tested positive for COVID-19<sup>18</sup>. Based on this experience, as well as similar statements from other expert groups<sup>19, 20</sup>, we recommend proceeding with tracheostomy after 10 days of mechanical ventilation, in those patients where spontaneous awakening trials (SAT) and spontaneous breathing trials (SBT) have failed. It is important to avoid extubation of patients with high likelihood of reintubation and instead, proceed with tracheostomy without undue delays. The high ventilator settings seen in COVID-19 patients with ARDS are not a

contraindication to proceed with tracheostomy although subcutaneous emphysema may be encountered<sup>21-23</sup>.

#### *Location*

We recommend placing tracheostomy tubes at bedside in the ICU rather than the operating room. This method confers multiple advantages including a controlled environment with nursing and respiratory therapy who have expertise in critical care. This location also offers the benefits of minimized use of PPE, minimized transport and therefore less contamination of other areas, and a reduced number of HCP involved in these highly aerosolizing procedures. The use of negative pressure rooms (including operating rooms) is strongly recommended but should be tailored to local availability and in coordination with Infection Control<sup>24, 25</sup>.

#### *Technique (Percutaneous vs. Open)*

The choice between surgical or percutaneous dilatational tracheostomy is largely determined by each institution's resources and expertise, as tracheostomies can be performed by surgeons and more often by non-surgeons<sup>26</sup>. Society guidelines may reflect a specific technique based on their general practice preference<sup>27</sup>. However, in patients with COVID-19 requiring a tracheostomy, the procedure should be performed by the most experienced operator, in the safest manner, using the shortest possible procedure duration, and preferably at the bedside to limit cross contamination during transportation. Based on these factors, we recommend the percutaneous technique which has been proven to provide these benefits<sup>28-30</sup>.

#### *Percutaneous Tracheostomy*

We recommend the use of bronchoscopy to minimize misplacement, bleeding from vessels located in the paratracheal area, and injury to the posterior wall of the trachea. However, if using bronchoscopy, one must selectively hold mechanical ventilation, and proceed expeditiously during the aerosolizing parts of the procedure. We recommend minimizing the number of personnel in the room and encourage the use of neuromuscular blockade. The experience of the two operators involved should ensure that the bronchoscopy portion as well as percutaneous tracheal access and introduction of the tracheostomy tube are done in rapid sequence. A novel technique recently described involves passing the bronchoscope alongside the endotracheal tube rather than through it<sup>18</sup>. This technique limits the visualization of the posterior wall at the time of the procedure, and also requires pulling back the endotracheal tube (ETT) with a deflated cuff when the tracheostomy tube is inserted. It also requires holding mechanical ventilation during specific steps, however, is an interesting alternative to the traditional bronchoscope-guided technique and was used with great success at the pioneering institution. A more detailed review of the standard technique is described in detail elsewhere<sup>31</sup>.

#### *Open/Surgical Tracheostomy*

In COVID-19 patients, special consideration should be given to the inherent need for transport to the OR, with the resulting increase in delays, HCP exposure during transportation and PPE use. Additional recommendations from the Society for Advanced Bronchoscopy guidelines advocate for minimizing tracheal suctioning, holding mechanical ventilation prior to incision of the trachea while deflating the cuff of the ETT to avoid accidental puncture, and using petroleum gauze around the site to minimize air leak<sup>32</sup>. A more detailed of the open/surgical tracheostomy technique is described elsewhere<sup>33</sup>.

*Tracheostomy tube choice*

The type of tracheostomy tube chosen for initial placement has a significant impact on future weaning and decannulation decisions. This is particularly important in patients with COVID-19 as procedures, are aerosol-generating. Appropriate size and model choices can minimize the need for future downsizing while providing an effective artificial airway. Characteristics such as inner diameter (ID), outer diameter (OD), angle, length, and presence of an inner cannula should all be taken into consideration (Table 1). The OD differs between tracheostomy models with the same ID. The OD plays a role during speaking and capping trials, as it determines to what degree the trachea is blocked by the tube and ultimately may impact the need for downsizing (Figure 2)<sup>34</sup>. We suggest the operator's primary consideration should be choosing the most effective ID, while minimizing OD. Tubes with an ID of 7 or 8 mm will fit most adults while providing both less airway resistance and the ability to perform bronchoscopy if needed. Tracheal size (sagittal and coronal dimensions) is smaller in females compared to males<sup>35-37</sup> and correlate with the patient's height<sup>36,38</sup>. We suggest choosing a tracheostomy tube with an ID of 7 mm for females with a height between 150-180 cm and for males with a height below 160 cm. In males taller than 160 cm and females over 180 cm, we recommend a tube with an ID of 8 mm. Specialized tracheostomy tubes i.e. extra-long tubes, flexible tubes, and adjustable flange tubes should be reserved for cases where the tracheal anatomy warrants it (patient body habitus and neck circumference). A good general rule is that if the punch-dilator needs to be hubbed to the skin to be visible during the percutaneous tracheostomy, the patient is likely to benefit from a longer tracheostomy tube, or an angle that allows it to clear the existing excess soft tissue.

Finally, a tube with a disposable inner cannula will reduce the ID by 1 mm and will result in increased resistance, but a disposable inner cannula may be helpful as it can be easily replaced if the tube becomes occluded<sup>39</sup>.

### **Placement of the Gastrostomy Tube**

#### *Rational for placement*

We recognize that percutaneous placement of a gastrostomy tube (PEG) may not be routine or available in all centers performing tracheostomies. Compared to a nasogastric tube (NG), a PEG tube provides more secure access to the GI tract. NG tubes are frequently dislodged and once they are replaced, they require x-ray confirmation of placement. This is particularly important in a COVID-19 positive patient as both the replacement and the x-ray will expose more providers to viral particles. NG tubes additionally can cause occlusive sinusitis and pressure ulcers in the nostrils and nasal septum, particularly in patients who have a lengthy recovery process. NG tubes also interfere with swallowing and can be more uncomfortable compared to a PEG tube. One key observation we have seen in these patients is the profound neuromuscular weakness and weight loss that occur, therefore securing uninterrupted nutrition is key. As retraining swallowing function and regaining strength/coordination to use feeding utensils can take weeks, a PEG tube remains the safest approach to transition to “spontaneous feeding trials”. Our recommendation of combining tracheostomy and PEG placement into one procedure is of particular importance during the COVID-19 pandemic as it minimizes HCP exposure on multiple levels.

#### *Timing*



For COVID-19 patients, the joint placement of percutaneous tracheostomy and PEG tubes combines these events into a single episode, performed by a highly efficient team with expertise in both procedures. This single timing placement minimizes the number of risky aerosol generation seen when performed at separate times and has the advantage of using one single anesthetic event. The practice patterns for placement of gastrostomy tubes for ongoing enteral nutrition versus continued nasogastric or orogastric temporary tubes are highly variable. The surgical placement of a gastrostomy tube could be considered in patients who are going to the OR for another indication.

#### *Location*

During the COVID-19 pandemic, limiting patient transfers to other areas of the hospital is important, therefore we recommend placement at the bedside, ideally coupled with tracheostomy placement to limit exposure to HCP. These procedures are considered AGPs and should ideally take place in a negative-pressure room.

#### *Technique*

Ultimately, the goal with COVID-19 patients is to decrease exposure to HCPs while providing efficient, effective and safe medical care, therefore we recommend endoscopic placement at the bedside. Gastrostomy tubes can be placed endoscopically, surgically, or by interventional radiology<sup>40, 41</sup> with the choice depending on local expertise, and less commonly on anatomic considerations. Regardless of which technique is chosen, it should be performed by an experienced operator. Appropriate PPE, which includes an N-95 mask, face shield, gown, and gloves should be worn throughout the procedure.



### **Caring for the COVID-19 patient with a tracheostomy**

#### *Identification of Aerosol Generating Procedures (AGP)*

Caring for patients on mechanical ventilation carries a risk of droplet or aerosol generation that may contaminate exposed individuals. As shown in Figure 1A, the risk depends on the degree to which the system is open to the environment. While the patient is in a closed system (shown in green), the caregiver and surroundings are less likely to be contaminated. The risk increases as the system becomes more open, such as when transitioning a patient to trach mask or performing a speaking valve trial (shown in red). Routine steps that are often performed during the prolonged care of these patient such as secretion clearance, suctioning for diagnostic samples, bronchoscopies and the administration of inhaled medications, are also higher risk procedures.

The general guiding principles are:

- Avoid unnecessary treatments: reconsider which maneuvers, or procedures are essential and avoid routine or automatic practices such as use of bronchodilators, routine tracheostomy tube changes or downsizing of the tracheostomy before assessing tolerance of capping.
- Favor procedures based on closed circuit techniques. When there are no alternatives, bundle high-risk tracheostomy care procedures (suctioning, tracheal manometry, capping, etc) to an individual care team, in a single setting.
- Within a closed-circuit set-up, use viral filters. Review manufacturer recommended filters and time for replacement and approved accessories to deliver inhaled therapeutics.
- Practitioner should abide by airborne precautions and wear proper PPE as recommended by the CDC. (<https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control.html>)

*Liberation from mechanical ventilation*

Liberation from mechanical ventilation is an important milestone in a patient's recovery from prolonged respiratory failure. In Figure 1A, we provide a general outline for the process of liberating patients from mechanical ventilation and their progress to decannulation. It is based on proven strategies that include assessment for readiness for spontaneous breathing trials<sup>42</sup>, a respiratory therapist (RT) driven weaning protocol<sup>43</sup> and an integrated tracheostomy decannulation protocol. In Figure 1B and Table 2 Section A, we highlight the suggested alternatives to key aerosol-generating steps in order to minimize HCP exposure risk to SARS-CoV-2.

While on mechanical ventilation, the risk of exposure to others is relatively low as the circuit is closed and few, if any, particles escape to the surrounding environment unless there is an air leak. The same is true if the patient has a capped tracheostomy tube, as the risk is similar to that of non-tracheostomized patients. If the patient is breathing with an oxygen or humidifying mask while the tracheostomy tube is open, or if they have been decannulated and the stoma is open, the risk for droplet or aerosol generation is high<sup>44-46</sup>. The risk while using a speaking valve with a humidifying mask is unclear.

Given the potential risks outlined, we suggest the following modifications:

1. When a patient reaches the SBT stage, it is best to consider continuous positive airway ventilation (CPAP) ventilation with enough support to compensate for the tube and circuit resistance (0/0 to 5/5 cm H<sub>2</sub>O pressure) instead of the open

- tracheostomy mask. This will allow suctioning and administration of inhaled therapies while decreasing the opening of the ventilator circuit, thereby diminishing the potential for exposure, without delaying liberation from mechanical ventilation.
2. When considering a valve to facilitate speech, we recommend using an in-line valve connected to the ventilator circuit.
  3. If tolerated, we recommend bypassing the speaking valve trial and proceeding directly to tracheostomy capping trials.
  4. If there is a need for liberating the patient from the ventilator or the patient cannot be decannulated, a T-piece with inline suction, viral filter and condensation collector is a feasible alternative (see Figure E1 of the online supplement).

#### *Secretion clearance*

The airway clearance procedures frequently performed in patients with prolonged respiratory failure are summarized in Table 2, Section B. Of these procedures, incentive spirometry is relatively safe but should only be used in patients where there is an indication, such as the presence of atelectasis. The same applies to mechanical insufflation-exsufflation (MIE) devices, which should only be considered for specific patients with ineffective cough<sup>47</sup>. The use of devices that require respiratory effort which results in expulsion of particles into the environment, such as flutter valves and oscillating positive expiratory pressure devices, should be avoided. For tracheal suctioning, we recommend performing in-line suctioning through a T-piece with a filter (Figure E1).

#### *Diagnostic maneuvers*

Assessing pulmonary mechanics to evaluate a patient's respiratory reserve is usually done via a closed system and thus is relatively safe. This is not the case when measuring exhaled end-tidal carbon dioxide (CO<sub>2</sub>) levels or performing tracheostomy tube manometry. In place of end-tidal CO<sub>2</sub> monitoring, we recommend using either venous or arterial blood gases to evaluate CO<sub>2</sub> levels or transcutaneous capnography if available<sup>48</sup>.

Tracheostomy tube manometry (Figure 2) can be a valuable tool to estimate a patient's readiness for use of a speaking valve or ability to tolerate capping. This maneuver measures the intra-tracheal airway pressures during inspiration and expiration as a surrogate of airflow resistance around the tracheostomy tube while the patient is spontaneously breathing. Expiratory pressures above 5 cm H<sub>2</sub>O and inspiratory pressures with values more negative than -3 cmH<sub>2</sub>O, suggest obstruction to airway flow and indicate the need for tracheostomy tube downsizing or airway inspection<sup>49</sup>. Although performing tracheal manometry requires a deflated cuff, it is quite informative regarding the need for tracheostomy downsizing. It is, however, aerosol generating and warrants the use of appropriate PPE in the COVID-19 patient.

#### *Therapeutic Procedures*

If a tube change is needed, the clinician should consider the current phase of the weaning process; if the patient requires mechanical ventilation then a cuffed tube is indicated, and we suggest replacing with either a tight-to-shaft (TTS®) model of the same size or a traditional cuffed model that is 1-2 sizes smaller. If the patient has been liberated from mechanical ventilation, we recommend assessing the need for a cuffed tracheostomy tube. The benefit of the TTS® or cuffless tube is that it does not create additional tracheal occlusion from the deflated

cuff. See the illustration in Table 1 and a suggested checklist for tracheostomy tube change in Table E2.

Bronchoscopy is sometimes needed in patients with chronic respiratory failure; however, it is considered a high-risk AGP. We refer you to issued guidelines for more specific information and indications for bronchoscopy amid the COVID-19 pandemic. Additionally, these documents provide recommendations on best practices, should bronchoscopy be performed<sup>32</sup>. (see Table 2 section C)

#### *Inhaled therapeutics*

In general, scheduled bronchodilators should be avoided unless the patient has a clear clinical indication. These therapies are not mandatory in all ventilated patients. Consider a long acting or ultra-long acting medication in order to minimize the number of potential exposures to those administering such medications. In patients who are mechanically ventilated, in-circuit nebulized or metered-dose inhalers (MDI) medications should be used preferentially, including long-acting medications. In tracheostomized patients, a long acting MDI with a spacer can be adapted to fit the tracheostomy tube. In patients who are decannulated, either a powder or mist-based delivery system is preferred (see Figure E2 for decision algorithm and Table E3 with a list of inhaled medications, administration routes and dosage frequencies).

### **Preparing for the Unexpected**

For accidental dislodgement of tracheostomy and/or PEG tubes, we strongly recommend having readily deployable PPE and barriers as these are all high-risk aerosol and droplet generating situations.

#### *Accidental displacement of the tracheostomy tube*

Accidental partial displacement or total decannulation of the tracheostomy tube occurs in up to 1.5% of tracheostomized patients and can result in significant hypoxia and death. We recommend following the suggested algorithm to manage accidental decannulation<sup>22, 50</sup> (see Figure E3 online supplement). All situations - oral intubation, bronchoscopic-guided or direct tracheostomy tube replacement, or close clinical monitoring with the tracheostomy removed - should be considered AGP in the COVID-19 patient.

#### *Accidental PEG removal*

Inadvertent removal of a gastrostomy tube may also occur, particularly in patients who are altered or combative. Similar to accidental decannulation, the management of accidental gastrostomy tube removal depends on how long the tube has been in place, and if there is a well-formed fistula track. Strategies are described in further detail elsewhere<sup>51, 52</sup>. In both early and late accidental dislodgement, rapid action should be taken to avoid closure of the stoma.

### **Conclusion**

The COVID-19 pandemic has impacted the delivery of care worldwide. A significant fraction of patients affected by SARS-CoV-2 will require prolonged mechanical ventilation and

percutaneous enteral nutrition. Careful coordination through the continuum of care to minimize aerosolization of viral particles is likely to have a beneficial impact on the safety of healthcare providers while minimizing the waste of personal protective equipment. The use of tracheostomy and gastrostomy tubes facilitates the transition of care from acute to sub-acute facilities thereby decreasing the burden on inpatient hospital systems; it also allows the weaning process to begin. The methods and algorithms described here should make the transition of mechanically ventilated COVID-19 patients from the intensive care they required to the long-term care they need not only more seamless, but also safe for everyone.

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**Figures Legends**

**Figure 1: Contrast of Management Strategies in Patients with Prolonged Mechanical Ventilation in the COVID-19 Era**

**Panel A:** Standard Management of Prolonged Respiratory Failure and Ventilator Weaning

**Panel B:** Suggested Modifications in Patients with COVID-19

**Footnotes:**

Abbreviations: \*SBT – spontaneous breathing trial; PEG – percutaneous endoscopic gastrostomy; PSV – pressure support ventilation; MV – mechanical ventilation; HME – heat moisture exchanger; SV – speaking valve



**Figure 2: Transtracheal Manometry**

**Legend:** To prepare a patient for manometry, the tracheostomy tube cuff is deflated, and secretions are suctioned. An adaptor is attached to the tracheostomy tube. The side port is connected via oxygen tubing to a pressure manometer that has been zeroed, and a speaking valve or cap (or finger occlusion with gloved finger) is attached to the end of the adaptor. The averaged inspiratory (negative) and expiratory (positive) pressures from at least five quiet breaths not during phonation or cough are recorded.

Low flow resistance is suggested when expiratory pressures are in the 0–5 cm H<sub>2</sub>O range. For capping, it is also important to measure the inspiratory pressures. Values between 0 and -3 cm H<sub>2</sub>O suggest low inspiratory resistance and capping is deemed safe. Values above 5 cm H<sub>2</sub>O for expiration and more negative than -3 cm H<sub>2</sub>O require careful consideration for either tube downsizing or airway inspection. Regardless of measurements, always observe the patient for overt signs and symptoms of difficulty breathing. More detailed information in reference <sup>49</sup>

Table 1: Comparison of commonly used tracheostomy tubes.


A. Open technique tracheostomy tubes*						
	Shiley™ SCT	Portex DIC®	Bivona® TTS	Portex® Blue Line Ultra®	Shiley™ Flex with TaperGuard	Shiley™ LPC & DCT
<b>Cuff</b>	Air	Air	Water	Air	Air	Air
<b>Angle</b>	75°	105°	100°	105°	88°	75°
<b>Material</b>	PVC	PVC	Silicone	PVC	PVC	PVC
<b>ID</b>	<b>OD</b>	<b>OD</b>	<b>OD</b>	<b>OD</b>	<b>OD</b>	<b>OD</b>
6	8.3	8.5	8.8	9.2	10.8	10.8
7	9.6	9.9	10	10.5	11.4	-
8	10.9	11.3	11	11.9	12.2	12.2
<b>ID</b>	<b>Length</b>	<b>Length</b>	<b>Length</b>	<b>Length</b>	<b>Length</b>	<b>Length</b>
6	67	64	70	64.5	74	76
7	80	70	80	70	77	-
8	89	73	88	75.5	79	81
*some models may be placed percutaneously as well						
B. Percutaneous specific tracheostomy tubes						
	Portex® Per-fit	Cook™ VersaTube™	Shiley™ Percutaneous Tracheostomy Tube	<p>Tracheal cross section</p> <p>ID: Inner diameter</p> <p>Inner cannula</p> <p>OD: Outer Diameter</p> <p>Added cross-sectional space taken by the deflated cuff</p>		
<b>Cuff</b>	Air	Air	Air			
<b>Angle</b>	113°	96°	-			
<b>Material</b>	PVC	PVC	PVC			
<b>ID</b>	<b>OD</b>	<b>OD</b>	<b>OD</b>			
6			10.8			
7	9.6	10				
8	10.9	11	12.2			
<b>ID</b>	<b>Length</b>	<b>Length</b>	<b>Length</b>			
6			74			
7	82	78				
8	86	86	79			


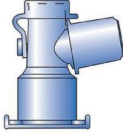
\*\*ID – inner diameter, OD – outer diameter, SCT – single cannula tracheostomy, DIC – disposable inner cannula, TTS – tight to shaft, LPC – low pressure cuff, DCT – disposable cannula tracheostomy

Table 1 footnote. With similar ID a tube's OD and length will differ by manufacturer and models.

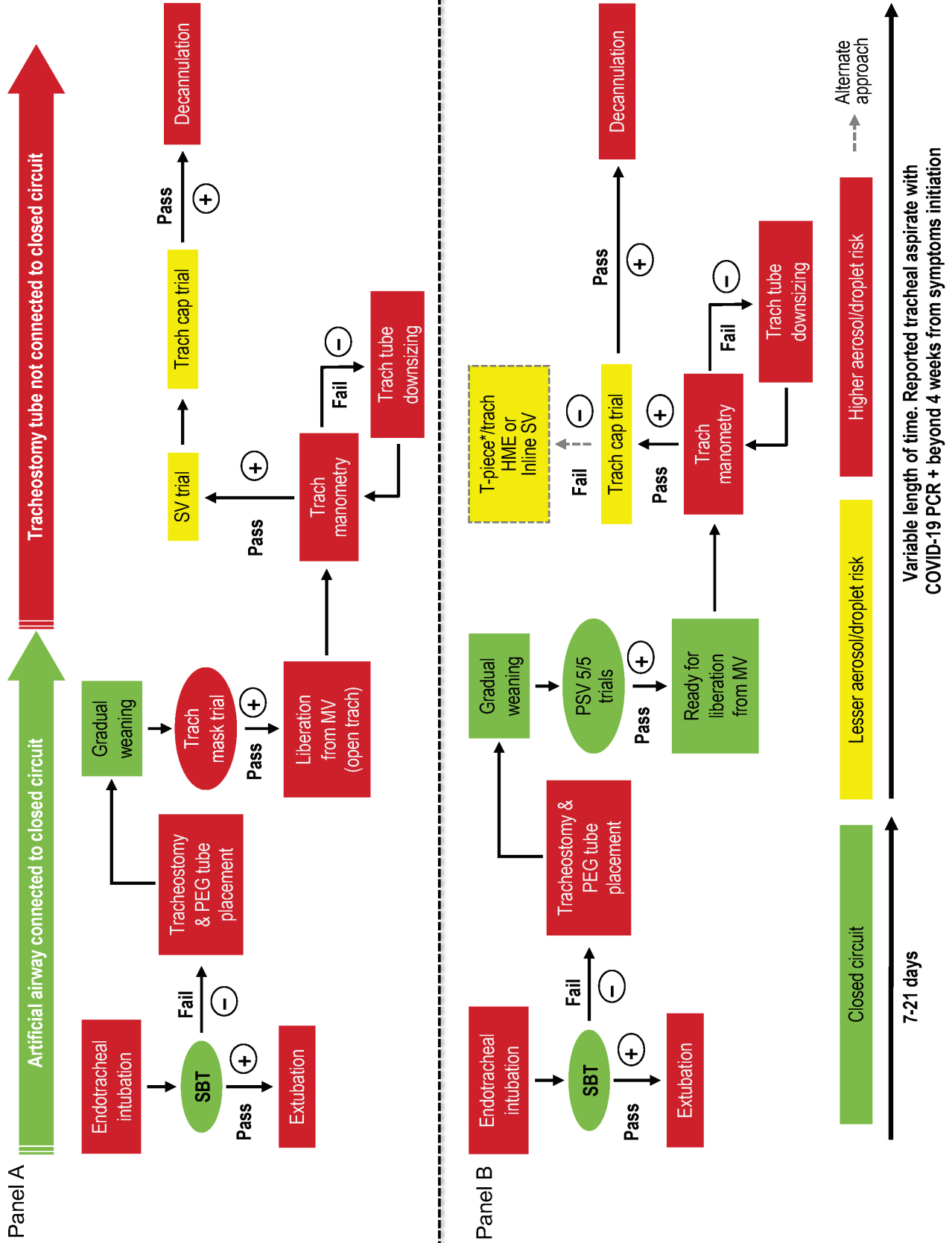
Although differences are 1 to 2 mm in range, we remind the reader of Poiseuille's law, in that airway resistance is influenced by the radius of a tube at the 4<sup>th</sup> power (for laminar flow) and at the 5<sup>th</sup> power for turbulent flow; this is the case in normal breathing at the tracheal level with an occluded tube partially obstructing its lumen(28). Note in the diagram that the cross-sectional area added by the deflated cuff is not accounted for in the specified OD except for in the Tight-to-Shaft model (TTS). The insertion of an inner cannula decreases the effective ID by 1 mm (see diagram representation). Dimensions are clearly stated in the tube's flange and packaging.

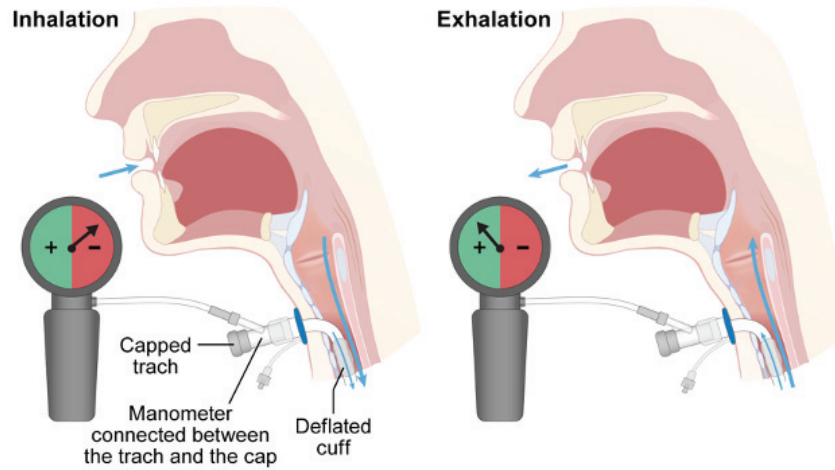
Table 2. List of suggested modifications to usual practice to reduce aerosol/droplet generation.

Current Practice	Suggested Modification	Notes/Comments	
<b>A. Weaning Process</b>			
<b>Mechanical ventilation</b>	None	By design done in a closed circuit, however, always monitor for air leaks	
<b>Pressure support wean</b>	None		
<b>SBT via trach mask</b>	SBT with pressure support 0/0, 0/5 or 5/5 to allow tube resistance compensation	Allows for in-line suction and therapeutics in closed circuit	
<b>One-way speaking valve (SV)</b>	If possible, skip 1-way SV and go directly to tracheostomy cap If needed use in-line SV	Scan the QR code to see demo of in-line SV	
<b>Trach cap</b>	None	Dressing over tracheostoma to avoid leaks. Patient to use face mask during interactions.	
<b>B. Secretion Clearance</b>			
<b>Tracheal suction (not on MV)</b>	T-piece with inline suction and filter (see Figure E1, online supplement)		
<b>Mechanical Insufflation/Exsufflation via trach (MIE)</b>	Indicated for patient with neuromuscular weakness Poor cough effort (PEF<160 LPM) (45)	Use a viral filter in the circuit Operator to wear enhanced airborne PPE Avoid face mask MIE	
<b>Flutter valves: Acapella®, Aerobika®</b>	Designed to loosen mucus and induce cough therefore is considered higher risk.		
<b>Incentive spirometry</b>	Probably okay	Use if suspect atelectasis	
<b>C. Procedures</b>			

<p style="text-align: center;">General precautions for all procedures:</p> <ul style="list-style-type: none"> <li>• For all procedures use airborne precautions as guided by the CDC</li> <li>• In addition, consider the use of additional physical barrier to contain droplets (clear plastic sheet or acrylic box)</li> </ul>		
<b>Tracheostomy tube downsize</b>	<ul style="list-style-type: none"> <li>• Need for downsizing guided by tracheostomy manometry (see text and Figure 2)</li> <li>• Avoid “routine” trach change</li> <li>• Always downsize to lower OD (see Table 1)</li> <li>• Consider a TTS cuff or cuffless model</li> </ul>	
<b>Bronchoscopy</b>	<p>Consider the use of a swivel adaptor instead of bronchoscope over open trach</p>	
<b>Decannulation</b>	<p>Follow general precautions above</p>	
<b>D. Diagnostics</b>		
<b>End tidal CO2</b>	<p>Use ABG-VBG</p>	<p>Must use proper PPE</p>
<b>Transtracheal manometry</b>	<p>None</p>	<p>Follow general precautions for all procedures as described above</p>
<b>Mechanics</b>	<p>Performed in-line using ventilator’s diagnostics and graphs</p>	

\*SBT – spontaneous breathing trial, SV – speaking valve, MV – mechanical ventilation, MIE - Mechanical Insufflation/Exsufflation PEF – peak expiratory flow, LPM – liters per minute, OD – outer diameter, PPE – personal protective equipment





To prepare a patient for manometry, the tracheostomy tube cuff is deflated, and secretions are suctioned. An adaptor is attached to the tracheostomy tube. The side port is connected via oxygen tubing to a pressure manometer that has been zeroed, and a speaking valve or cap (or finger occlusion with gloved finger) is attached to the end of the adaptor. The averaged inspiratory (negative) and expiratory (positive) pressures from at least five quiet breaths not during phonation or cough are recorded.

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