GUIDELINES

# Procedures in COVID-19 Patients: Part-I

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## Abstract

The number of cases with novel coronavirus disease-2019 (COVID-19) infection is increasing every day in the world, and India contributes a substantial proportion of this burden. Critical care specialists have accepted the challenges associated with the COVID-19 pandemic and are frontline warriors in this war. They have worked hard in streamlining workflow isolation of positive patients, clinical management of critically ill patients, and infection prevention practices. With no end in sight for this pandemic, intensive care unit (ICU) practitioners, hospital administrators, and policy makers have to join hands to prepare for the surge in critical care bed capacity. In this position article, we offer several suggestions on important interventions to the ICU practitioners for better management of critically ill patients. This position article highlights key interventions for COVID-19 treatment and covers several important issues such as endotracheal intubation and tracheostomy (surgical vs PCT), nebulization, bronchoscopy, and invasive procedures such as central venous catheters, arterial lines, and HD catheters.

**Keywords:** Aerosols, Airway, Bronchoscopy, Central venous catheter, COVID-19, Diagnostic procedure, Emergency, Intubation endotracheal, Nebulizers, SARS-CoV-2, Tracheostomy.

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## Tracheal Intubation and Tracheostomy

Tracheal intubation and tracheostomy are the most commonly performed procedures in critically ill patients.[1] In the intensive care unit (ICU), coronavirus disease-2019 (COVID-19) patients may require tracheal intubation for inadequate oxygenation, ventilation, aspiration risk, inability to maintain a patent airway, poor level of consciousness, and sometimes in anticipation of a deteriorating course that may lead to respiratory failure. A tracheostomy on the other hand may be required in select patients who have a need for a prolonged intubation (due to long-term ventilation, aspiration risk, or poor level of consciousness), facilitate weaning from mechanical ventilation, tracheal toileting, or bypassing an obstructed upper airway.

Critically ill patients have a physiologically difficult airway. The emergent nature of airway management, increased risk of aspiration, variable levels of operator skills, and the complex environment often pose significant challenges during airway management, with increased risk of complications.[1] Both tracheal intubation and tracheostomy are considered to be aerosol-generating procedures (AGP).[2] Thus, maintaining patient safety while protecting the health care worker (HCW) from getting infected during airway management is paramount and challenging. This can be achieved by carefully implementing specific measures during airway management to mitigate the spread of the virus.[3] The "do's" and "don'ts" for tracheal intubation and tracheostomy in COVID-19 patients in the intensive care unit (ICU) are summarized in Table 1.

### Understanding Aerosol Generation and Control during Tracheal Intubation and Tracheostomy

The SARS-CoV-2 virus is transmitted via contact, inhalation of respiratory droplets (5–10 μm diameter), and generation of aerosol particles (<5 μm diameter). The procedures involving respiratory tract like tracheal intubation and tracheostomy cause major aerosolization of the virus, increasing the risk of viral transmission.[4,5] The World Health Organization (WHO) recommends the use of airborne, droplet, and contact

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**Table 1:** Do's and don'ts for tracheal intubation and tracheostomy in intensive care unit (ICU)

| *Steps* | *Do's* | *Don'ts* |
|---|---|---|
| General measures | | |
| Environment | • Negative pressure room if feasible<br>• Keep the room door closed<br>• Optimum number of air exchanges in ICU | • Positive pressure room<br>• Non-essential staff around during the procedure |
| Team preparation | • Preferably two operators (one experienced in airway management)<br>• Team briefing before the procedure regarding concerns, roles, communication plan and rescue strategy<br>• Wear appropriate PPE | |
| Tracheal intubation | | |
| Preoxygenation | • A heat and moisture exchange filter (HMEF) attached between the ventilator circuit and the mask and another one attached between the expiratory limb of the circuit and the ventilator<br>• Side stream capnography tubing is attached to the machine end of the HMEF<br>• Two-hand technique for mask holding with a good seal<br>• Use waveform capnography to monitor for leaks | • Increased interval between removal of surgical mask and placement of the face mask<br>• Use of noninvasive ventilation (NIV)<br>• Use of high flow nasal oxygen (HFNO) |
| Induction of Anesthesia | • Rapid sequence intubation<br>• Use appropriate doses of rocuronium or suxamethonium | • Bag-mask ventilation<br>• Use of HFNO |
| Tracheal intubation (TI) | • Performed by the most experienced operator<br>• Use a videolaryngoscope<br>• Initiate mechanical ventilation only after inflating the cuff of the endotracheal tube (ETT)<br>• Use waveform capnography to confirm tracheal placement of the ETT | • Repeated attempts at TI<br>• Use of a stethoscope |
| Tracheostomy | | |
| Tracheostomy | • Outweigh the benefit and risk of procedure<br>• Delayed until at leastday 10 of mechanical ventilation and only when patient is improving clinically<br>• Performed by an experienced operator<br>• Maintenance of a bloodless field, minimal use of diathermy and use of a smoke evacuator during surgical tracheostomy<br>• The tracheostomy tube should be pushed distally and the cuff hyper-inflated<br>• Start ventilation only once a closed circuit is established with the tracheostomy tube cuff inflated<br>• Use a closed suction system | • Disconnection of the ventilator circuit during the tracheostomy<br>• Ventilation when the ETT is being withdrawn and the tracheostomy tube is inserted<br>• Use of an uncuffed/fenestrated tracheostomy tube |

precaution while performing AGPs.[6] The airway operator should don PPE and N95 mask, which are effective against aerosols. If available, a powered air purifying respirators (PAPR) may be used instead of the N95 masks. Performing these procedures in a negative pressure room will help prevent the spread of the virus outside the room and thus prevent infecting other HCWs.[3] The aerosols usually tend to remain in the air for a few hours, and the number of air exchanges changes in the ICU will determine proportion of the potentially virus-bearing aerosols present in the air. Each air exchange will replace 63% of the air, and therefore after five air exchanges, less than 1% of the aerosols should remain.[7]

## General Preparation for Airway Management in COVID-19 Patients

*Team Preparation*

- Minimize the airway management team (preferably two persons).
- Only essential staff should be around the patient during the procedure.
- To increase the chance of first pass success with airway management and minimize the exposure time, the best skilled airway operator among the team members should perform the procedure.
- Advance team briefing should include discussion on concerns, roles, communication plan, and rescue strategy.
- Communication after donning PPE is challenging, especially in the use of critical language during an airway emergency.[6] The method of communication after donning PPE should be discussed.
- Supervised donning of standard PPE.

*Patient Preparation*

- The patient should be wearing a surgical mask before tracheal intubation
- Take a brief history and perform examination (including fasting status and airway examination)
- Check consent and coagulation status before performing a tracheostomy
- Secure an intravenous line and start intravenous fluids.

*Environment Preparation*

- Perform the procedure preferably in a negative pressure isolation room if available.
- Check that all equipment required for airway management, monitoring and mechanical ventilation are available and functioning.

## Tracheal Intubation in COVID-19 Patients

*Equipment*

- Video laryngoscope (VL), bougie/stylet, lubricant jelly, size appropriate oropharyngeal/nasopharyngeal airway and endotracheal tubes (ETT), Magill forceps, 10 mL syringe, tube tie and tape, second-generation supraglottic airway devices (SGA), equipment for surgical cricothyroidotomy, and nasogastric tube
- Mechanical ventilator, face mask, and ventilator circuit with one heat and moisture exchange filter (HMEF) and a bacteria virus filter (BVF) (with 99.99% filtering efficiency)
- Drugs induction agents, neuromuscular blocking agents, and vasopressors
- Monitoring device for ECG, blood pressure, oxygen saturation ($SpO_2$), and continuous end tidal $CO_2$ waveform ($EtCO_2$)
- Piped oxygen and suction

*Preoxygenation*

- Attach the HMEF between the ventilator circuit and the mask and the BVF between the expiratory limb of the ventilator circuit and the ventilator. The side stream capnography tubing is attached to the machine end of the HMEF.
- Position the patient appropriately. Minimize the time between removal of the patient's mask and the application of the face mask.
- Preoxygenation with 100% oxygen for 3–5 minutes using a tight-fitting face mask and a two-hand technique. High-flow nasal oxygen and noninvasive ventilation should be avoided for preoxygenation as they generate aerosols.
- Continuous waveform capnography should be used if available. During preoxygenation, a triangular rather than a square $EtCO_2$ waveform or a low $EtCO_2$ value may indicate a leak around the face mask and should prompt interventions to improve the seal.[8]

*Induction of General Anesthesia*

- Rapid sequence induction (RSI) is the preferred method to avoid mask ventilation and facilitate faster tracheal intubation.[3,8,9]
- To avoid cardiovascular collapse, consider the use of ketamine or etomidate for induction of anesthesia.
- Appropriate doses of rapidly acting neuromuscular blocking drugs such as rocuronium or suxamethonium should be used to achieve complete muscle relaxation before tracheal intubation.
- Avoid mask ventilation to prevent aerosol generation, unless necessary. If required, mask ventilation should be done with a tight mask fit using a two-hand technique to prevent leak around the face mask. Apneic oxygenation with HFNO should be avoided.[8]

*Tracheal Intubation*

- VL-assisted tracheal intubation is recommended to keep the face away from the oral cavity and increase the chance of first pass intubation success.
- It is preferable to use an ETT having subglottic suction and preload it with a stylet or use a bougie as appropriate.
- Cricoid pressure, if applied, should be removed in case of difficulty in glottis visualization.
- After tracheal intubation, the ETT cuff should be inflated and the HMEF connected directly to the ETT. Ensure that there is no leak around the ETT cuff.
- Mechanical ventilation should be initiated only after the ETT cuff is inflated.
- Confirm ETT placement in the trachea using waveform capnography. Use of a stethoscope is not feasible while wearing PPE. Note and record the depth of ETT insertion.
- Use a vasopressors bolus or infusion if there is hypotension.
- A closed suction system should be used.
- Place a orogastric tube after tracheal intubation and ventilation is achieved.
- If a circuit disconnection is required, put the ventilator on a standby mode.
- Keep the HMEF connected to the ETT during the disconnection. However, if a HMEF change is required or a tracheal aspirate needs to be collected, clamping the ETT transiently may be considered.[8]

## Unanticipated Difficult Tracheal Intubation

When faced with an unanticipated difficult tracheal intubation, mask ventilation using a two-person two-hand technique should

be used only if the $SpO_2$ is not maintained. A further attempt at tracheal intubation is recommended only if the $SpO_2$ is maintained. Use of a second-generation SGA is recommended in case of a failed tracheal intubation. Tracheal intubation through the SGA or performing a tracheostomy may be required for long-term mechanical ventilation in ICU. In the event of a complete ventilation failure (inability to ventilate using an ETT, SGA or face mask despite the best effort), it is recommended to proceed with a surgical cricothyroidotomy.[3] It is important to keep in mind that the abovementioned procedures performed during airway rescue are also aerosol generating.

### Tracheostomy in COVID-19 Patients

#### *Patient Selection for Tracheostomy*

Tracheostomy is a high-risk procedure due to aerosol generation, which puts HCW at increased risk of SARS-CoV-2 infection. Among non-COVID-19 patients who require a tracheostomy for prolonged mechanical ventilation, almost 50% do not survive for more than a year and at 1 year less than 12% are functionally independent at home.[10] Thus, it is important to consider the benefits of performing a tracheostomy in these patients, against the risk of infection to the HCW. The available healthcare resources with respect to tracheostomy maintenance should also be considered before performing a tracheostomy during the COVID-19 pandemic.

#### *Timing of Performing Tracheostomy*

It may be prudent to delay performing a tracheostomy until active COVID-19 disease is resolved. Although delaying tracheostomy for patients with COVID-19 might reduce infection risk to HCW, prolonged tracheal intubation, sedation, mechanical ventilation, and ICU stay associated with such delays may lead to complications. The median time from SARS-CoV-2 exposure to onset of symptoms (incubation period) is approximately 5 days (range 4–14). SARS-CoV-2 is normally most abundant around the time of symptom onset. After symptom onset, viral load typically decreases over the following 3–4 days.[11,12] Therefore, it is recommended that tracheostomy should be delayed until atleast day 10 of mechanical ventilation and considered only when patients are improving clinically.[13]

#### *Surgical vs Percutaneous Tracheostomy*

Aerosol generation between percutaneous and surgical tracheostomy techniques in COVID-19 patients has not been compared. Percutaneous dilatational tracheostomy (PDT) is a standard bedside technique used in ICU, and the use of ultrasound and bronchoscopy guidance has increased its safety. PDT usually involves opening the ventilator circuit more often than surgical tracheostomy (ST). Use of disposable bronchoscopes with a sealed ventilator circuit is preferable when performing PDT.[13] An ST may necessitate shifting to operating room increasing the risk of aerosol generation and risk of exposure to HCW. There is no evidence regarding the superiority of either technique in reducing infectivity or complications in patients on anticoagulants, including those on extracorporeal membrane oxygenation support.[13] Therefore, the tracheostomy technique preferred should be determined by the local expertise and resources. The operator should do tracheostomies using the techniques and equipment with which they are familiar and experienced with.

#### *Important Tips for Tracheostomy in Intubated Patients with COVID-19*

Anesthesia with neuromuscular blockade should be administered to avoid any movements or coughing during the procedure. Perform a tracheal suction only if required. The patients should be ventilated with an $FiO_2$ of 100% before the procedure. Ventilation should be stopped during insertion of the tracheostomy tube to minimize aerosol spread, and apneic oxygenations should continue with the same $FiO_2$ and a positive end expiratory pressure of 5 cm $H_2O$. Positive pressure ventilation should be avoided as far as possible, unless the $SpO_2$ drops. The ventilator circuit with the HMEF should be attached to the tracheostomy tube. Ventilation should commence only once a closed system is established. The position of the tracheostomy tube should be confirmed by the presence of a consistent capnography trace.

#### *Disposal and Decontamination of Contaminated Equipment*

Single-use items should be discarded in the appropriate disposal bag and reusable items dropped into the container with disinfectant solution as per infection control protocol. Careful doffing of the PPE should be performed under supervision to avoid contamination after the procedure.

## Nebulization in COVID-19 Patients

Aerosol therapy is commonly used in patients with lung disease and during mechanical ventilation in ICU. Nebulizers are devices used for administering medication like bronchodilators, antibiotics, etc., by spraying a fine mist in the respiratory tract. Nebulized aerosol particles range in size from 1 to 5 µm.[14] Nebulization is associated with release of aerosols during patient's exhalation and is a cause of concern in COVID patients. The exhaled aerosols (fugitive emissions) contain particles ranging from 0.860 to 1.437 µm, and up to 50% of the generated aerosol may remain suspended as airborne particles in the indoor environment for several hours.[15] Recent reports suggest that aerosol transmission of SARS CoV-2 is plausible because virus can remain viable and infectious in aerosols for hours.[5]

Pressurized metered dose inhalers (pMDI) with a spacer and dry powder inhalers (DPI) are used for aerosol therapy at home. pMDI and jet nebulizers are commonly used in the hospital setting, whereas, jet, ultrasonic and vibrating mesh nebulizers are used in intubated patients on ventilator.

Pressurized MDI (pMDI) and dry powder inhalers (DPI) are inhalers and not good choices in COVID patients with acute respiratory failure. These devices are breath actuated (DPI) and require specific flows to draw and disperse medication which may not be generated by patients in respiratory distress.[16] Moreover, it is cumbersome to use pMDI in ventilated patients because a spacer with MDI has to be integrated in the ventilator circuit. The MDI actuation can be coordinated with start of inspiration only if it is integrated in the ventilator. Another drawback is the need for disconnection of the HME filter during nebulization and reconnection after it is over. Awake and spontaneously breathing asthmatic patients with mild COVID-19 can use pressurized MDI with a reservoir or dry powder inhalers (DPI), if aerosolized medications are important for control of asthma.[17]

A Jet nebulizer uses a jet of oxygen or compressed air and can be used either with an oxygen facemask or connected to inspiratory limb of the ventilator circuit. Ventilators with integrated jet nebulizers provide reproducible and consistent dosing during

inspiration, whereas the jet nebulizer connected to oxygen mask and a compressed air source gives a continuous aerosol spray. Conventional jet nebulizers may spew two-third of emitted aerosol into ambient environment during aerosolized therapy.[18]

The HCW may get exposed to fugitive emissions much more during jet nebulization, as they can emit two-third of the medication aerosol into the environment.[19] Driving gas up to 10 L/minute can increase dispersion of both medical and bioaerosols. Facemask combined with jet nebulizers have highest fugitively emitted aerosol concentration.[2] Although previous studies have not found evidence of virus in the air samples taken from 30 cm above the patient's head in SARS outbreak, a recent CDC report in SARS-CoV-2 pandemic observed that while caring for an asymptomatic unsuspected patient, 121 unprotected HCW were exposed and 43 developed symptoms and were treated for the virus.[19,20] Jet nebulizers should be used with a mouthpiece or large bore devices with one-way valve.

As per CDC, there is no linkage between nebulization and increased risk of SARS-CoV-2 infection, but they recommend airborne precautions and use of full PPE's during nebulization.[20,21] The UK government guidelines advise continued use of nebulization, as administration of medication via nebulization does not represent a significant infection risk, as exhaled aerosols are mostly drug aerosols and when they come in contact with patient's mucus membrane, they cease to be airborne and do not pose a risk.[22,23] However, due to lack of clear scientific evidence, the issue remains controversial, and it is recommended that in the absence of any conclusive evidence, and new data are still being obtained, proper precautions should be used per the current guidelines consensus to prevent the spread of SARS-CoV-2.[23]

Ultrasonic nebulizer's performance depends on frequency and amplitude of vibration, and a drawback is a reduced performance after a few minutes due to increase in viscosity of drug solution. The generated aerosol particle size is larger than with jet nebulizers. Ultrasonic nebulizers are generally integrated with the ventilators and are more efficient than have a jet nebulizer but are relatively inefficient in nebulizing drug suspensions.

Vibrating mesh nebulizers generate aerosols with a high fine-particle fraction and are more efficient than jet or ultrasonic nebulizers. They have the advantage of being portable, battery or electrically operated, and leave a minimal medication residual volume in the device. In spontaneously breathing patients who are on oxygen therapy, mesh nebulizers can be used with mouthpiece using a filter or HEPA filter at the other end of the mouthpiece. These nebulizers also come integrated in the ventilator system and can stay in circuit for up to 28 days and can be actuated to deliver the aerosol during the inspiratory phase. Mesh nebulizers are ideal, as the reservoir is isolated from breathing circuit, and its design allows drug to be added with any break in ventilator circuit. These nebulizers can be placed before the humidifier, which not only make them efficient but also reduce retrograde contamination from the patient.[24,25]

The exhaled particles from intubated patients are less than 2 µm that do not deposit via sedimentation or inertial impact. As a general precaution, expiratory filter/HEPA filters can be placed at the expiratory port of ventilator to significantly reduce the risk of exhaled aerosols suspension in air. One study found that drug deposited in expiratory ports without filters was >160-fold higher than with expiratory filters.[26]

Aerosolized therapy in combination with chest physiotherapy and suction is not recommended, as coughing may generate significant aerosols droplet nuclei capable of transmitting the virus. In-line closed suction catheters can be used for up to 7 days without a break in circuit to minimize aerosol risk.

If aerosolized medication is mandatory and has to be given to the patient, such patients should be isolated in airborne infection isolation room (AIIR) or negative pressure rooms with minimum 12 air changes per hour or at least 160 L/min in areas with natural ventilation. It is important that HCW wear PPEs, including a gown overall, face shield, gloves, and an N 95 respirator mask.[27] Entry into these areas should be restricted, and those who are not involved in direct contact with the patient should not be allowed.

### Suggestions

- Avoid unnecessary aerosol therapy.
- If needed, corticosteroid and bronchodilator therapy in asthmatics may have to be continued.
- COVID-19 patients with mild illness who are awake and spontaneously breathing can be given pMDI with spacer.
- Avoid using pMDI in ventilated patients due to breakage of circuit for placement of device in the ventilator circuit.
- Jet nebulizers
  - Are associated with significant fugitive emission and bioaerosol generation putting HCW at risk.
  - Should not be used with a facemask, as the bioaerosol generation is very high.
  - If required should be used with a mouthpiece or large bore device with one-way valve.
  - Are not ideally suited for ventilated patients as they need to be connected and disconnected with exposure risk to HCW.
- Mesh nebulizers
  - Can be used with mouthpiece using a filter or HEPA filter at the other end of the mouthpiece in spontaneously breathing patients.
  - Are ideal for ventilated patients and can stay in circuit for up to 28 days. The reservoir design allows drug to be added with any break in ventilator circuit.
  - Placing an expiratory filter at the exhalation port significantly reduces aerosol exposure.

*Recommendations*

- Avoid unnecessary aerosol therapy.
- Full PPE including an overall gown, N95 respirator, face shield, and gloves must be worn by HCW when the patient is on nebulization.
- Patient requiring aerosolized medication should ideally be isolated in airborne infection isolation room (AIIR) or negative pressure rooms with minimum 12 air changes per hour or at least 160 L/minute in areas with natural ventilation.

## Bronchoscopy in COVID-19 Patients

Bronchoscopy is an essential diagnostic and therapeutic technique for a variety of respiratory diseases including pneumonias.[28,29] The positive bronchoalveolar lavage and bronchial brush specimens are considered sensitive indicators of lung infections and are established diagnostic methods. But bronchoscopy is an AGP and causes significant aerosol generation, exposing the HCW to a

high risk of infection.[29–31] AGP have a potential to transmit disease if the bronchoscopy team does not take adequate precautions, and unprotected HCWs participating in the procedure have the potential of becoming a super spreader.[32,33]

The role of bronchoscopy in diagnosis of SARS CoV-2 has been debated in the bronchology associations due to high potential for bioaerosol generation, and some broad recommendations have emerged.[29,31] The experts agree that bronchoscopy is not an appropriate tool for diagnosis of SARSCoV-2 infection because the risks involved outweigh the benefits.[28,29] It is suggested that the physicians should take a detailed history, including travel, contact with COVID-19 patient, and epidemiological factors in suspected cases. In the background of high local prevalence of COVID-19 cases, clinically, a combination of fever, cough, breathing difficulty, flu-like symptoms, and radiographic evidence of bilateral pneumonia or ground-glass opacities should raise suspicion of COVID-19.[14,17] For all such suspected cases, collection of upper respiratory samples via nasopharyngeal and oropharyngeal swabs and a positive RT-PCR should be the primary and preferred method for diagnosis for SARS CoV-2.[28,29,33]

## Intensive Care Unit Bronchoscopy

Bronchoscopy is relatively contraindicated in patients with suspected and confirmed COVID-19 infections.[28,29] Its use should be limited for the diagnosis of SARS CoV-2 in intubated patients, where upper respiratory tract samples are negative in the background of a clinical suspicion of COVID-19 disease or for diagnosing any other disease where bronchoscopy would significantly change the clinical management.[28,33] A good alternative in the intubated patient is tracheal aspirates and non-bronchoscopic alveolar lavage (N-BAL) if bronchoscopy is to be totally avoided.[28,34–36]

It is also suggested that bronchoscopy for patients with non-malignant or preinvasive conditions should be postponed if there is no significant risk to the patient.[29,33] However, if bronchoscopy is unavoidable, all patients should be subjected to COVID RT-PCR testing for upper respiratory tract samples prebronchoscopy.[29,33] These patients may be categorized according to their COVID-19 status as confirmed, probable, not probable, or negative. Probable should include patients with history, clinical features, and radiology highly suggestive of COVID-19, irrespective of RT-PCR result. Patients who are clinically and radiologically not suspected of COVID and are RT-PCR negative should only be labeled as negative.[28,29,37,38]

If RT-PCR for COVID-19 is positive before the procedure, bronchoscopy should be postponed unless urgently required. Bronchoscopy should be avoided for at least 28 days from onset of infection. A telephonic reassessment should be done after 28 days for fitness for bronchoscopy. Those with continuing symptoms should be advised to self-isolate for a further 7 days, followed by repeat assessment.[28,29,33,37]

## Elective Bronchoscopy in Confirmed (COVID-19) or Probable Positive Patients

Diagnostic reason may include a lung mass, bronchial mass, mediastinal or hilar lymphadenopathy, lung infiltrates, and mild to moderate airway stenosis or the nasopharyngeal smear that is negative two times and clinically there is still diagnostic uncertainty of COVID-19 infection or other diagnoses are considered that would significantly change clinical management.[14,18,22] For diagnostic bronchoscopy, tracheobronchial lavage using a few milliliters or BAL is recommended. No other diagnostic procedures such as transbronchial biopsy or needle aspiration should be performed in the same procedure.[28,33,38,39]

## Emergency Bronchoscopy in Confirmed Cases

Bronchoscopy is commonly used in lobar and complete lung collapse during mechanical ventilation, where physiotherapy, prone positioning, or recruitment maneuvers have been unsuccessful. It can also be considered for a therapeutic life-saving intervention (hemoptysis, higher grade benign or malignant central airway stenosis, or foreign body aspiration), or to identify issues such as bronchial migration of endotracheal tube.[28,29,31,33] In rare situation of a bronchoscopy need in patients undergoing veno-venous extracorporeal membrane oxygenation (ECMO), platelets should be >50/μL, and anticoagulation should be stopped a few hours before the procedure and ACT should be monitored. Specimens should be stored and processed according to the biosafety requirement.[28,29,31,33]

## Bronchoscopy Personal Protective Equipment and Precautions

Donning (putting on) and doffing (taking off) areas for PPEs should be created for the HCW, and strict discipline should be enforced.[31,33] In COVID-19 patients requiring emergency bronchoscopy procedure, standard PPEs including gown, gloves, face shield, and N-95 respirators or powered air purifying respirators, should be used before, during, and after the procedure.[28,29,31,33]

The staff involved in bronchoscopy should include only the bronchoscopist, ICU technician, and a nurse, and only trained personnel should be present when performing any specimen collection. The lab should be alerted regarding COVID-19 specimen processing and testing before the procedure. No observers, students, apprentices, or trainees should be near the patient. All PPEs including N95 mask should be discarded in the doffing area after the procedure.[28,31,40,41]

Disposable bronchoscopes can be utilized if available. If reusable bronchoscope is used, standard high-level disinfection/sterilization procedures should be followed for bronchoscope and related equipment. Ideally, bronchoscopy in intubated patients should be performed in negative pressure rooms with at least 12 air changes per hour, or the area should be adequately ventilated, with air flow of at least 160 L/s per patient. General anesthesia with muscle relaxant is recommended in COVID-19 patients to reduce aerosol production. BAL should be avoided in patients with $SpO_2$ <92% on supplemental oxygen.[29,33,40,41]

## Suggestions

- Bronchoscopy has a very limited role in COVID-19 patients.
- PPE should be used by all HCWs who perform bronchoscopy or are present in the bronchoscopy room. PPEs include gown, gloves, face shield, and N-95 respirator (a must).
- Bronchoscopy should be considered in intubated patients only if
  - upper respiratory samples are negative,
  - there is a strong clinical suspicion of COVID-19, and
  - another diagnosis is being considered that would significantly change clinical management.
- BAL should be avoided. If lower respiratory samples are required for diagnosis of COVID-19 or secondary lung infection, a tracheal aspirate through closed suction catheter is adequate.
- Flexible or rigid bronchoscopy should only be undertaken as a life-saving intervention for indications like:
  - massive hemoptysis
  - benign or malignant severe airway stenosis
  - suspicion of alternate or secondary infectious etiology

- malignant condition with significant endobronchial obstruction.

## Invasive Procedures in COVID-19 Patients

The COVID-19 pandemic has brought the safety of the healthcare personnel to the fore, even more so than the HIV epidemic. The Ebola epidemic was comparable but was restricted in geographical area. Patients with COVID-19 require vascular access for many reasons: peripheral venous access for intravenous fluids and drugs, arterial access for hemodynamic monitoring and blood gas sampling, central venous access for long-term venous access, vasopressor and other drug administration, parenteral nutrition, and possibly pressure monitoring. In addition, large bore vascular access is needed for performing hemodialysis and ECMO. This vascular access needs to be established minimizing the risks to the HCW without compromising good clinical care.

The requirement for vascular access differs with the severity of the disease and the type of healthcare facility. Patients with mild symptoms usually require just a peripheral venous access for hydration, supportive therapy, and blood sampling. They may also require an arterial access for frequent blood gas analysis, especially in obese patients where repeated access may not be feasible and in academic institutions where ABG may be the standard of care in such patients. Severely ill patients admitted to the ICU may require the full panoply of vascular access.

### Choice of Device: Peripheral Venous Access

- A simple peripheral venous cannula suffices in most cases. However, this requires regular resetting to prevent thrombophlebitis. It also has the potential to be dislodged, as the patients are encouraged to self-prone.
- If available and feasible, a 20-cm catheter inserted in the arm with the tip placed in the axillary vein has the advantages of long duration, high flow, low risk of dislodgment, and facility for sampling.[42] Ultrasound can be used to verify the tip position.

### Suggestions

- In the COVID-19 patients who do not require admission to intensive care unit (ICU), use of a peripheral venous access device is preferable.
- A long peripheral cannula (a.k.a. "mini-Midline," 6–15 cm) or a standard midline catheter (15–25 cm) rather than a short cannula (<6 cm) should be preferred. Due to their longer dwell time, it will reduce the number of peripheral venous insertions thereby reducing the risk of infection in the HCW. These peripheral devices allow high-flow infusions, ease of blood sampling, and can be easily converted to a peripherally inserted central catheter (PICC) over a guidewire.

### Choice of Device-Central Venous Access

- A PICC is probably the most suitable device. It is usually as good as the centrally inserted central catheters (CICC), capable of high flows, and appropriate for pressure and cardiac output monitoring.[43–45]
- The risk of thrombosis and infection are primarily dependent on good insertion technique and are similar to that of CICC.[46] In addition, placement of this device takes the operator away from the airway of the patient and may allow better respiratory therapy for the patient. However, the cost may be a deterrent in our country.
- When a CICC is to be placed, a subclavian approach should be preferred.
- All the central lines should be guided by ultrasound whenever feasible.[39]
- Intracavitary electrocardiography, transthoracic echocardiography, and chest X-ray may be used to ensure appropriate tip positioning depending on availability of equipment and expertise.[47]

### Suggestions

- Keep the catheter away from the endotracheal tube. Use of femoral access (FICCs) may be considered to minimize the risk of operator contamination by the patient's oral, nasal, and tracheal secretions. Exit site at mid-thigh will keep it away from the groin and contamination.
- When a CICC is to be placed, it is recommended that a subclavian approach be used, which offers advantages, such as long-term use, patient comfort, and distancing of the operator from the patient's airway.
- If there is no contraindication, use low-molecular-weight heparin in all patients in prophylactic (100 units/kg/24 hour) or therapeutic (100 units/kg/12 hour or 150 units/kg/24 hour) doses to reduce the risk of thrombosis.

### Choice of Device: Arterial Access

- A 20-G arterial cannula inserted in the radial artery after modified Allen's test will suffice for the vast majority of the mild to moderately ill patients. Ultrasound guidance may be useful in obese patients.
- For long-term use, a 20-G catheter placed in the radial artery using a Seldinger technique with the tip in the brachial artery is safer.

### Precautions for Avoiding Contamination

CDC recommendations for vascular access must be strictly followed.[19] These standard maximal barrier precautions include

- Hand hygiene
- Surgical mask
- Beret
- Sterile impermeable gown
- Sterile gloves
- Wide sterile drapes for the patient, and
- Appropriate sterile cover for the ultrasound probe.

### Suggestions

- At the time of insertion, the operator should adopt the standard barrier precautions to protect the patient (hand hygiene, skin antisepsis with 2% chlorhexidine in 70% isopropyl alcohol, non-sterile surgical mask, non-sterile cap, sterile gloves, waterproof sterile gown, and wide sterile field on the patient).
- If the patient is on a ventilator, the risk of aerosol generation is very less due to the closed circuit. Any disconnection from the ventilator during the procedure should be avoided.
- For personal protection the operator should wear standard PPE aimed at preventing contact (double gloves, full body suit, goggles/face shield, N95 respirator mask or its European equivalent FFP2 mask).

- Special care must be taken when there is high risk of aerosol in the environment (extubated and symptomatic COVID patient on NIV/high flow oxygen).

### Step-by-step Procedure for Vascular Access (Peripheral Venous, Arterial, and Central Venous)

- Don appropriate PPE as per institutional guidelines.
- Assemble all the equipment needed beforehand
  - The intravenous fluid bottle with infusion set (venous access)
  - Heparinized saline bottle with infusion set and three-way stopcocks or preferably needleless injectors (Clave or Qsite, etc) (central venous and arterial)
  - Pressure infusion bag (central venous and arterial)
  - Kidney tray with heparinized saline
  - Syringes, three-way stopcocks/needleless injectors, pressure lines
  - Equipment for cleaning the site (chlorhexidine or povidone iodine solution, cotton swabs)
  - Sealable bag for disposal of used equipment
  - Sharps container
  - Choose the appropriate device for vascular access (cannula and catheter)
  - Choose the ultrasound probe to be used beforehand, for example, a hockey stick probe for arterial cannulation.
- Put on sterile gown and gloves
- Preparation of the ultrasound machine
  - Position the sterile cover on the probe and secure it
  - Ensure probe is connected securely to the machine
  - Switch on the machine and check the probe
  - Cover the machine, including the display but excluding the probe, with a transparent plastic sheet
- Preparation of the patient
  - Ensure that the patient is wearing a N95 mask if on room air. If patient is on ventimask, a surgical mask over it is appropriate. If on HFNC, ensure that a screen is placed between the procedure site and the patient's head and face. Turning the head away is recommended.
  - Ensure appropriate counseling/sedation of the patient.
  - Appropriate cleaning of the site
  - Full body draping of the patient, especially during central venous catheterization.
- Performing the procedure
  - Avoid using open-ended puncture devices. Always have a syringe and if possible a 3-way attached.
  - Avoid counter-puncture technique
  - Endeavour to avoid any spillage of blood
- Cleanup
  - All waste material should go into appropriate sealable containers, including the sharps and the plastic drape covering the ultrasound machine and the patient drapes
  - The ultrasound probe cover should be retained and disposed.
  - Doffing should be done carefully under supervision to avoid contamination.

### Personal Protective Equipment for Healthcare Worker Cleaning the Intensive Care Unit/Spills

- Wear appropriate PPE that would include the following while carrying out cleaning and disinfection work.
- Wear disposable rubber boots, gloves (heavy duty), and a triple-layer mask
- Gloves should be removed and discarded if damaged, and a new pair worn.
- All disposable PPE should be removed and discarded after cleaning activities are completed.
- Do not keep wearing the same pair of gloves for the whole day.
- Hands should be washed with soap and water immediately after each piece of PPE is removed, following completion of cleaning.
- Masks are effective if worn according to instructions and properly fitted. Masks should be discarded and changed if they become physically damaged or soaked.
- Do not take used masks home. The used masks at ICU/Critical care area should be discarded.

## References


1. Russotto V, Myatra SN, Laffey JG. What's new in airway management of the critically ill. Intensive Care Med 2019;45(11):1615–1618. DOI: 10.1007/s00134-019-05757-0.
2. Cook TM, Harrop-Griffiths W. Aerosol clearance times to better communicate safety after aerosol-generating procedures. Anaesthesia 2020;75(8):1122–1123. DOI: 10.1111/anae.15146.
3. Patwa A, Shah A, Garg R, Divatia J, Kundra P, Doctor J, et al. All India Difficult Airway Association (AIDAA) consensus guidelines for airway management in the operating room during the COVID-19 pandemic. IJA 2020;64(14):107–115. DOI: 10.4103/ija.IJA_498_20.
4. Wang W, Xu Y, Gao R, Lu R, Han K, Wu G, et al. Detection of SARS-CoV-2 in different types of clinical specimens. JAMA 2020;323(18):1843–1844. DOI: 10.1001/jama.2020.3786.
5. Lockhart SL, Duggan LV, Wax RS, Saad S, Grocott HP. Personal protective equipment (PPE) for both anesthesiologists and other airway managers: principles and practice during the COVID-19 pandemic. Canad J Anaesth 2020 67(8):1005–1015. DOI: 10.1007/s12630-020-01673-w.
6. Brewster DJ, Chrimes N, Do TB, Fraser K, Groombridge CJ, Higgs A, et al. Consensus statement: Safe airway society principles of airway management and tracheal intubation specific to the COVID-19 adult patient group. Med J Aust 2020;212(10):472–481. DOI: 10.5694/mja2.50598.
7. Coia JE, Ritchie L, Adisesh A, Makison Booth C, Bradley C, Bunyan D. Healthcare infection society working group on R and facial P. Guidance on the use of respiratory and facial protection equipment. J Hosp Infect 2013;3(3):170–182. DOI: 10.1016/j.jhin.2013.06.020.
8. Cook TM, El-Boghdadly K, McGuire B, McNarry AF, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19: Guidelines from the Difficult Airway Society, the Association of Anaesthetists the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetists. Anaesthesia 2020;75(6):785–799. DOI: 10.1111/anae.15054.
9. Vargas M, Sutherasan Y, Brunetti I, Micalizzi C, Insorsi A, Ball L, et al. Mortality and long-term quality of life after percutaneous tracheotomy in intensive care unit: a prospective observational study. Minerva Anestesiol 2018;84(9):1024–1031. DOI: 10.23736/S0375-9393.18.12133-X.
10. Guan W, Ni Z, Hu Y, Liang W-H, Ou C-Q, He J-X, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 2020;382(18):1708–1720. DOI: 10.1056/NEJMoa2002032.
11. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA 2020;323(11):1061–1069. DOI: 10.1001/jama.2020.1585.
12. McGrath BA, Brenner MJ, Warrillow SJ, Pandian V, Arora A, Cameron TS, et al. Tracheostomy in the COVID-19 era: global and multidisciplinary

guidance. Lancet Respir Med 2020;8(7):717–725. DOI: 10.1016/S2213-2600(20)30230-7.
13. Salna M, Tipograf Y, Liou P, Chicotka S, Biscotti M, Agerstrand C, et al. Tracheostomy is safe during extracorporeal membrane oxygenation support. ASAIO J 2020;66(6):652–656. DOI: 10.1097/MAT.0000000000001059.
14. McGrath J, O'Toole C, Joyce GBM, Mac Loughlin R. Investigation of fugitive aerosols released into the environment during high flow therapy. Pharmaceutics 2019;11(6):254. DOI: 10.3390/pharmaceutics11060254.
15. van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Eng J Med 2020;382(16):1564–1567. DOI: 10.1056/NEJMc2004973.
16. Ari A. Practical strategies for a safe and effective delivery of aerosolized medication to patients with COVID-19. Respir Med 2020;167:105987. DOI: 10.1016/j.rmed.2020.105987.
17. Recommendations for inhaled asthma controller medications, Global Initiative for Asthma 2020 https://ginasthma.org/recommendations-for-inhaled-asthma-controller-medications.
18. Ari A. Jet, mesh and ultrasonic nebulizers: An evaluation of nebulizers for better clinical practice. Eur J Pulmonology 2014;16(1):1–7. DOI: 10.5152/ejp.2014.00087.
19. Wan GH, Tasi YH, Wu YK, Tsao KC. A large volume nebulizer would not be an infectious source for severe acute respiratory syndrome. Infect Control Hosp Epidemiol 2004;25(12):1113–1115. DOI: 10.1086/502353.
20. Heinzerling A, Stuckey MJ, Scheuer T, Xu K, Perkins KM, Resseger H, et al. Transmission of COVID-19 to healthcare personnel during exposure to a hospitalized patient-Solano county, California, Feb 2020. MMWR Morb Mortal Wkly Rep 2020;69(15):472–476. DOI: 10.15585/mmwr.mm6915e5.
21. Centers for Disease Control and Prevention. Coronavirus disease 2019 (COVID-19) healthcare infection prevention and control FAQs for COVID-19. Updated April 23, 2020 https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-faq.html. Updated July 7, 2020.
22. United Kingdom Government. New and Emerging Respiratory virus Threats Advisory Group (NERVTAG). https://www.gov.uk/governemnt/publications/wuhan-novel-coronavirus-infection-prevention-and control/cpvod-19-personal-protective-equipment-ppe.
23. Tashkin DP, Barjaktarevic IZ. Nebulized treatments and the possible risk of coronavirus transmission: where is the evidence? Chronic Obstr Pulm Dis 2020;7(3). DOI: http://doi.org/10.15326/jcopdf.7.3.2020.0161.
24. Ari A, Arbaei H, Fink JB. Evaluation of position of aerosol devices in two different ventilator circuits during mechanical ventilation. Respir Care 2010;55:837–844.
25. Berlinski A, Willis JR. Albuterol delivery by 4 different nebulizers placed in 4 different positions in a paediatric ventilator in vitro model. Respir Care 2013;58:1124–1133. DOI: 10.4187/respcare.02074.
26. Ari A, Fink J, Harwood R, Pilbeam S. Secondhand aerosol exposure during mechanical ventilation with and without expiratory filters: an in-vitro study. Indian J Respir Care 2016;5:677–682.
27. Rationale use of personal protective equipment for coronavirus disease 2019 (COVID-19) World Health Organization, 2020, at https://apps.who.int/iris/bitstream/handle/10665/331215/WHO 2019-nCoV-IPCPPE_use-2020, 1-eng.pdf.
28. Wahidi MM, Lamb C, Murgu S, Musani A, Shojaee S, Sachdeva A, et al. American Association for Bronchology and Interventional Pulmonology (AABIP) statement on the use of bronchoscopy and respiratory specimen collection in patients with suspected or confirmed COVID-19 infection. J Bronchol Interv Pulmonol 2020. DOI: 10.1097/ LBR.0000000000000681.
29. Ost DE. Bronchoscopy in the age of COVID-19. J Bronchol Interv Pulmonol 2020;27:160–167. DOI: 10.1097/LBR.0000000000000682.
30. Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J, Aerosol-generating procedures and risk of transmission of acute respiratory infections: a systematic review. Ottawa (ON): Canadian Agency for Drugs and Technologies in Health; 2011. Available from https://www. ncbi.nlm.nih.gov/pmc/articles/PMC3579388/10.1371/journal.pone.0035797.
31. CDC–Center for Disease Control and Prevention. Interim infection prevention and control recommendations for patients with suspected or confirmed coronavirus disease 2019 (COVID-19) in healthcare settings https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html. Page last reviewed: June 3, 2020.
32. World Health Organization. Q&A on coronaviruses (COVID-19). https://www.who.int/newsroom/q-a-detail/q-a-coronaviruses.
33. Luo F, Darwiche K, Singh S, Torrego A, Steinfort DP, Gasparini S, et al. Performing bronchoscopy in times of the COVID-19 pandemic: practice statement from an international expert panel. Respiration 2020;99(5):417–422. DOI: doi.org/10.1159/000507898.
34. Namendys-Silva SA. Respiratory support for patients with COVID-19 infection. Lancet Respir Med 2020;8(4):e18. DOI: 10.1016/S2213-2600(20)30110-7.
35. Novel Coronavirus Pneumonia Emergency Response Epidemiology Team. Vital Surveillances: The Epidemiological Characteristics of an Outbreak of 2019 Novel Coronavirus Diseases (COVID-19)—China, 2020. China CDC Weekly 2020, 2: pp. 113–122.
36. World Health Organization. (2020). Laboratory testing of 2019 novel coronavirus (2019-nCoV) in suspected human cases: interim guidance, 17 January 2020. World Health Organization. https://apps.who.int/iris/handle/10665/330676. License: CC BY-NC-SA 3.0 IGO.
37. Zhang J, Tian S, Lou J, Chen Y. Familial cluster of COVID-19 infection from an asymptomatic. Crit Care 2020;24(1):119. DOI: 10.1186/s13054-020-2817-7.
38. Bai Y, Yao L, Wei T, Tian F, Jin DY, Chen L, et al. Presumed asymptomatic carrier transmission of COVID-19. JAMA 2020;323(14):1406. DOI: 10.1001/jama.2020.2565.
39. Lamperti M, Bodenham AR, Pittiruti M, Blaivas M, Augoustides JG, Elbarbary M, et al. International evidence-based recommendations on ultrasound-guided vascular access. Intensive Care Med 2012;38(7):1105–1117. DOI: 10.1007/s00134-012-2597-x.
40. NICE – National Institute for Health and Care Excellence. Coronavirus (COVID-19). https://www.nice.org.uk/guidance/ng159 Published date: 20 March 2020 Last updated: 29 April 2020.
41. Robert Koch Institut. BMG/BMAS/ABAS/RKI: Resource-saving use of mouth-nose protection (MNS) and FFP masks (14.4.2020) https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Ressourcen_schonen_Masken.pdf.
42. Qin KR, Nataraja RM, Pacilli M. Long peripheral catheters: Is it time to address the confusion? J Vasc Access 2019;20(5):457–460. DOI: 10.1177/1129729818819730.
43. Cotogni P, Pittiruti M. Focus on peripherally inserted central catheters in critically ill patients. World J Crit Care Med 2014;3(4):80–94. DOI: 10.5492/wjccm.v3.i4.80.
44. Sanfilippo F, Noto A, Martucci G, Farbo M, Burgio G, Biasucci DG. Central venous pressure monitoring via peripherally or centrally inserted central catheters: a systematic review and meta-analysis. J Vasc Access 2017;18(4):273–278. DOI: 10.5301/jva.5000749.
45. D'Arrigo S, Sandroni C, Cacciola S, Dell'Anna AM, Pittiruti M, Annetta MG, et al. P199 single-lumen 5Fr and triple-lumen 6Fr peripherally inserted central catheters (PICCs) for cardiac output assessment by trans-pulmonary thermodilution. Crit Care 2020;24(Suppl. 1):87. DOI: 10.1186/s13054-020-2772-3.
46. Balsorano P, Virgili G, Villa G, Pittiruti M, Romagnoli S, De Gaudio AR, et al. Peripherally inserted central catheter-related thrombosis rate in modern vascular access era-when insertion technique matters: a systematic review and meta-analysis. J Vasc Access 2020;21(1):45–54. DOI: 10.1177/1129729819852203.
47. Iacobone E, Elisei D, Gattari D, Carbone L, Capozzoli D. Transthoracic echo-cardiography as bedside technique to verify tip location of central venous catheters in patients with atrial arrhythmia. J Vasc Access 2020. 1129729820905200 10.1177/1129729820905200.