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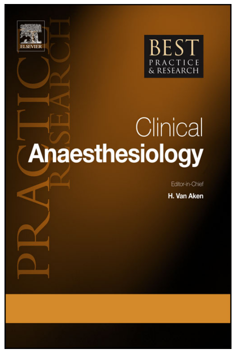

Clinical recommendations for in-hospital airway management during aerosol-transmitting procedures in the setting of a viral pandemic

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Abstract (146 words)

The coronavirus disease 2019 (COVID-19) pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), can lead to severe pneumonia and multi-organ failure. While most of the infected patients develop no or only mild symptoms, some need respiratory support or even invasive ventilation.

The exact route of transmission is currently under investigation. While droplet exposure and direct contact seem to be the most significant ways of transmitting the disease, aerosol transmission appears to be possible under circumstances favored by high viral load. Despite the use of personal protective equipment (PPE), this situation potentially puts healthcare workers at risk of infection, especially if they are involved in airway management.

Various recommendations and international guidelines aim to protect healthcare workers, although evidence-based research confirming the benefits of these approaches is still scarce. In this article, we summarize the current literature and recommendations for airway management of COVID-19 patients.

Keywords: COVID-19, aerosol-transmitted viral diseases, airway management, intubation, critical care, narrative review

Introduction

As of mid-November 2020, COVID-19—the illness caused by the novel severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2)—has been responsible for more than 54 million confirmed infections and 1,300,000 deaths worldwide[1]. Due to the highly infectious nature of the virus — with a high viral load in human airways — establishing precise and safe airway management guidelines is essential to protect healthcare workers and bystanders.

SARS-CoV-2 is mainly transmitted by droplet spread and by contact with infected patients and contaminated surfaces, but infection is also possible through airborne spread, especially after aerosol-generating procedures (AGP)[2]. Droplet and airborne spread differ in the size of the suspended particles. Aerosols are airborne particles that evaporate but remain in the air longer before settling on surfaces (airborne transmission). In particular, particles that are 5 μm or smaller can survive in the air for a long time, and directly enter the lower respiratory tract of a person [3]. Although there is no clear cutoff between large and small droplets[4-6], SARS-CoV-2 can be transmitted either way, so taking precautions to prevent contact and airborne spread is crucial[7, 8].

COVID-19 primarily causes severe viral hypoxemic pneumonia, with or without multiorgan dysfunction. Critical care is needed for around 5% of the patients, and mortality varies considerably between countries, with the case fatality ratio worldwide having reached 2.4 by November 2020[1]. Most of the patients—especially those who are young (under the age of 65) and 80-90% of those without comorbidities—develop only mild symptoms or no symptoms at all [9-11]. This makes it more difficult to track and isolate potentially infectious subjects and to slow down or stop the spread of the virus.

Various societies involved in airway management have published guidelines and recommendations for the treatment of COVID-19 patients [12-21]. We aim to summarize how airway management recommendations have evolved over the course of the present pandemic, and to suggest how clinicians can benefit from new guidelines to be prepared for future aerosol-transmitted diseases[22, 23], with a focus on aerosol-generating procedures (AGP) and their risk to healthcare workers (Table 1).

Risk for health care workers

The odds ratios for infection of healthcare workers involved in the care of patients with the severe acute respiratory syndrome (SARS) in Table 1 are based on a review published in 2012 containing low-grade to very low-grade evidence [23]. A number of procedures are associated with potential infection.

The unknown number of asymptomatic COVID-19-positive patients was probably underestimated, especially at the beginning of the pandemic [24]. Elective procedures are being performed again, and the discipline required for testing, maintaining distance from contacts, and limiting social interaction may drop.

An international prospective multicenter study found that performing an intubation places the involved healthcare workers at high risk of infection (up to 10%)[25].

Table 1. Aerosol-generating procedures (AGP) identified by the US Centers for Disease Control and Prevention [26] and odds ratios (OR) for the risk of SARS transmission for healthcare workers exposed vs. not-exposed to SARS (Tran et al.[23])

Aerosol-generating procedure (AGP)	Estimate OR
Tracheal intubation and extubation	6.6
Manual ventilation	1.3 - 2.8
Tracheotomy or tracheostomy procedures (insertion or removal)	4.2
Bronchoscopy	1.9
Non-invasive ventilation (NIV)	3.1
High-flow nasal cannula (HFNC)	0.4
High-frequency oscillatory ventilation (HFOV)	0.7
Induction of sputum using nebulized saline	0.9
Respiratory tract suctioning (before and after intubation)	1.3 - 3.5

Chest compressions during cardiopulmonary resuscitation (CPR)	1.4
Abbreviations: SARS: severe acute respiratory syndrome	

Risks of airway-related procedures

The risk of transmission or infection is increased for healthcare workers during aerosol-generating procedures (AGPs) [7, 27, 23] due to the high virus concentration in the patient's upper airway and sputum [28]. Protection of workers involved in airway management must be a high priority, and personal protective equipment (PPE) should be available for the whole team involved in treating suspected or confirmed COVID-19 patients. To minimize the risk of multiple transmissions, the number of healthcare personnel involved in an aerosol-generating procedure should be reduced to the minimum, while maintaining the patient's safety at all times. All of these procedures are best performed in rooms with negative pressure or with air exchange rates of up to 6-12 times per hour [29, 12, 13]. Some authors even suggest avoiding rooms with positive pressure (e.g., operating rooms (OR) for airway procedures [13]. However, the recommendation seems to be difficult to apply due to lack of availability of emergency rooms (ERs), ORs and intensive care units (ICUs). A preoperative huddle consisting of all staff involved in the care of the patient is important to improve teamwork and reduce unnecessary exposure [30].

Tracheal intubation

A severe COVID-19 infection can lead to acute respiratory failure and therefore requires emergency intubation. Such patients are characterized by very high viral spread[31]. The point at which intubation is indicated may differ from institution to institution and also may be influenced by the existing resources in an acute pandemic situation, such as the availability of beds with mechanical ventilation and ICU care, or the possibility to relocate an intubated patient. Evidence is lacking with regard to the best time for intubation, but the current recommendations tend to avoid emergency intubation of unstable patients, instead providing early intubation in order to protect the involved employees [32, 13, 12]. Adapting an institution's existing airway management algorithms to the pandemic situation seems to be the most appropriate approach, due to prior experience and high acceptance [13, 33-37].

Some published consensus guidelines [12, 21, 13] suggested the creation of dedicated intubation teams. These teams should be composed of an experienced airway manager and 1-2 assistants per patient, regardless of whether COVID-19 is confirmed or suspected. Reducing the number of potentially exposed persons and the exposure time during an AGP can potentially shorten workers' exposure to a high viral load and could be one of the keys to minimizing new infections. Team members should be familiar with the airway tools, monitoring equipment, ventilators and drugs used to safely perform tracheal intubation. Simulation training of airway management and PPE can significantly increase adherence to standards and therefore the safety of patients and healthcare providers [21]. The method of communication has to be established before the procedure starts, and should result in an "airway plan". Clear the procedure for every team member, and try to communicate directly and in a closed-loop manner, both within your team and with any teams from other disciplines [12].

Preoxygenation should be performed for 3-5 minutes [32, 17, 38] with a good sealed mask and rapid sequence induction [12]. There is evidence of decreased desaturation rates with low-flow apneic oxygenation (oxygen 1-5 l/min) provided by a conventional nasal cannula during intubation [39, 40]. Although strong evidence is lacking, it seems unlikely that such procedures produce a relevant amount of aerosol [12]. There is a strong consensus that video laryngoscopy (VL) should be preferred [13, 29, 12] as it offers some distance between the healthcare professional and a potentially extremely high virus load in comparison with direct laryngoscopy (DL)[31]. In patients with a difficult airway, VL improves glottic view, reduces airway trauma [41] and can increase first-pass intubation success[42]. In general, the use of a standard blade is recommended, with a hyperangulated blade as a backup. The choice of equipment should always be adapted to the skill and clinical judgement of the care provider performing airway management [13]. In case of the unavailability of VL or unfamiliarity with this tool, well-known standard procedures should be performed instead of experiments with unfamiliar ones [33, 12].

Practicing rapid sequence induction (RSI) in patients with very limited pulmonary function and almost nonexistent respiratory reserve is already challenging. In this context, induction medications with rapid effect and a deep neuromuscular block to suppress coughing should be mandatory. The recommendations for neuromuscular blocking agents (NMBAs) favor rocuronium [12] in a dosage between 1.2 mg/kg and 1.5 mg/kg ideal body weight (IBW)[13] and sugammadex available in case of an unexpected difficult airway[43]. If succinylcholine is used as the NMBA, the recommended dosage is 1 mg/kg [43] up to 1.5 mg/kg total body weight (TBW)[12, 13]. An international consensus on how to perform rapid sequence induction is still lacking [44].

Induction of anesthesia for intubation exposes the patient to an increased risk of hemodynamic instability or even cardiac arrest. In patients susceptible to significant hemodynamic fluctuations, consider ketamine at a dosage of 1-2 mg/kg for a hemodynamically stable induction and have vasopressors ready to use during the intubation phase [12]. An easy way to administer norepinephrine in such situations is 10 mcg/ml as a push dose.

A common concern of healthcare workers which should be taken into consideration is that massive exposure to COVID-19 can occur during intubation. A recent study showed that tracheal intubation—including facemask ventilation—produced rather low quantities of aerosolized particles compared to extubation and much less than a coughing patient[45]. Therefore, there is strong agreement that coughing should be avoided whenever possible. This underlines the importance of a deep neuromuscular block during airway procedures.

After intubation the cuff should be inflated immediately and a viral filter should be connected at the end of the tube before starting positive pressure ventilation [13, 12, 29]. Expiratory capnography has to be monitored continuously [12]. Auscultation of the chest can be challenging when wearing a full PPE, and provides a potential risk of contamination; therefore it may not be feasible. If correct placement of the tube needs to be verified, a chest radiograph should be considered after potential central lines or catheters have been installed [13]. Alternatively, point-of-care ultrasound (POCUS)[46] can be used to assist in determining endotracheal tube depth and to rule out a pneumothorax, if needed [29].

Bag–mask ventilation

Nowadays, careful bag-mask ventilation is acceptable while performing a rapid sequence induction [47]. Nevertheless, as a recognized aerosol-generating procedure it should be avoided whenever feasible in suspected or confirmed COVID-19 patients, unless it is a rescue maneuver to treat an unexpected difficult airway [48, 13, 29].

These patients present with a higher risk of hypoxia, and mask ventilation should be considered in some cases [10]. If indicated and applied, sealing of the mask is crucial, and a filter needs to be placed directly after the mask to minimize the dispersion of aerosols. To achieve a good seal, the two-handed V-E grip[49] can be used with a two-person-technique. Oropharyngeal airways such as Guedel's or Wendel's may be used to ensure an open airway [50], and minimal positive pressure and low oxygen flow should be applied. Monitoring the bag-mask ventilation with continuous wave capnography is important in order to detect possible leaks [51]. Some authors suggest placing two wet tissues between face and mask to achieve a better seal [43], but there is no evidence supporting this technique. If it is not possible to achieve a good seal with the mask, and careful ventilation seems unattainable, a supraglottic airway device (SAD) should be inserted. This is considered to be safer and produces less aerosol [13].

Airway manipulation

If disconnection of the tracheal tube of an intubated patient is necessary, proper preparation helps to minimize the amount of aerosol generated and the amount of time it takes to disperse. To help avoid a coughing patient, consider deep sedation and profound muscle relaxation before the procedure starts. If no direct access to the airway is necessary, the tracheal tube should be clamped between the filter and the patient after the patient has inhaled, in order to maintain the positive end expiratory pressure (PEEP) generated and therefore to avoid atelectasis during this maneuver [12]. Open suctioning, bronchoscopy, and disconnection of the ventilator circuit should be avoided unless necessary, since these can generate aerosols. If possible, a closed suctioning system should be installed [52, 43].

Extubation

Extubation is considered a high-risk AGP due to the high likelihood of coughing and possible agitation while the endotracheal tube is being removed. Extubation produces up to 15 times more aerosols than intubation[45]. A number of techniques have been developed to reduce aerosol production and droplet spread during extubation. Physical protection—such as consequent use of PPE and early application of a surgical mask to the patient's face—seems to best protect staff from being contaminated [53, 54, 12]. The number of healthcare workers involved should be reduced to the minimum. Extubation under deep sedation is not recommended due to possible absence of spontaneous ventilation, prolonged time with an unsecured airway, increased risk of aspiration and therefore increased risk of requiring bag-mask ventilation and re-intubation. Medications suppressing coughing, such as opioids, lidocaine or dexmedetomidine, may be considered as preventive measures [55] [12, 13].

Non-invasive ventilation

Indications for non-invasive ventilation (NIV) in patients with acute respiratory distress syndrome (ARDS) or COVID-19 are beyond the scope of this review. In general, NIV and humidified application of aerosolized (nebulized) medications should be avoided [13, 29] in aerosol-transmitted viral diseases, to protect healthcare workers until evidence is available from randomized controlled trials. A review article published in 2014 in the context of influenza A H1N1 reported transmission to staff caring for patients treated with NIV in one study out of 22 [56]. A recently published review article reports that the risk of transmission of COVID-19 to healthcare workers may be increased [57]. However, if NIV is used, it is recommended that the treating practitioners wear full PPE and that isolated areas be used to protect the staff and other patients [13, 29].

Supraglottic airway device

It still remains unclear if and how much aerosol is generated by inserting—and removing—a SAD[33]. If a SAD is leaking or patients are coughing at its removal, it is very likely that aerosols will be generated. In the management of an airway due to pulmonary exacerbation in symptomatic COVID-19 patients who will be intubated anyway for long-term ventilation, SAD might play a role as a rescue tool in an unanticipated difficult airway. If one is using SAD for general anesthesia, the provider should keep the risk of the AGP in mind. The leak may be smaller with a spontaneously breathing patient, but if the anesthesia is too "light" there may be an increased risk of coughing [33]. A SAD of the second generation is believed to produce less aerosol than bag-mask ventilation [13].

High-flow nasal cannula

The use of high-flow nasal cannulas (HFNCs) is controversial. A retrospective analysis by Patel et al. [58] postulated that they reduce the incidence of intubation and lead to better outcomes in the case of severe COVID-19 infections. Some earlier randomized controlled trials have shown benefits of high-flow nasal cannula therapy in the context of acute respiratory failure— caused by pneumonia and without hypercapnia—compared to conventional oxygen therapy to prevent NIV and invasive mechanical ventilation [59, 60]. Nevertheless, in some cases necessary intubation may be delayed [12]. These findings have not been decisively demonstrated [61-63].

Although the use of HFNCs is highly suspected of generating aerosols, the amount still remains unclear, and is thought to be smaller with newer models [12]. As HFNCs are on the list of aerosol-generating procedures[64], there might be an increased risk of significant aerosol exposure for healthcare workers, even if there is low evidence. Instead of completely banning the cannulas, however, hospitals should evaluate their risks and benefits [13, 33, 65]. There are differences between using HFNCs to avoid desaturation during airway instrumentation or with the intention of delaying or preventing an intubation that could lead patients to a long period of mechanical ventilation.

If the use of HFNCs is considered, it should be subject to the same safety precautions as NIV. This means that the healthcare workers providing the treatment need to wear PPE, and treatment should only be provided in areas with isolation of airborne particles [13]. In addition, during a pandemic, there is a need to conserve resources as much as possible. In fact, even oxygen supply may be scarce [12], and the use of HFNCs may contribute to depleted reserves.

Emergency front-of-neck airway (eFONA) and tracheostomy

In “can't intubate, can't oxygenate” (CICO) situations, a surgical emergency front-of-neck airway (eFONA) created with scalpel and bougie may be preferred over a needle technique[12]. Attempts to oxygenate via bag–mask ventilation during the procedure should be avoided to minimize the risk of generating aerosols [13, 12].

Tracheostomy is common for patients who need long-term ventilation, but it is considered a high aerosol-generating procedure [66]. Even though there is evidence of better patient outcomes in early compared to late tracheostomy [67], those findings are not specific to COVID-19 patients, and the best time to perform a tracheostomy in these patients remains controversial. One taskforce recommended that extended endotracheal intubation be considered in order to protect healthcare workers[68], but a recent cohort study showed that tracheostomy can be a safe procedure if performed by an experienced team wearing PPE [69]. Deep neuromuscular blockade is recommended to prevent the patients from coughing while tracheostomy is performed[70].

Awake tracheal intubation and expected difficult airway

Awake tracheal intubation (ATI) is a procedure performed on patients with expected or known difficult airways [71]. It is usually performed with a flexible endoscope, but can also be performed with video laryngoscopes [72] or rigid optics such as the C-MAC VS (Karl Storz, Tübingen, Germany). ATI is an aerosol-generating procedure, which is performed while in close proximity to the spontaneously breathing patient.

Due to reductions in elective surgeries in a pandemic situation, the clinical load of such cases —more likely to be found in ENT surgery—will decrease [33]. Nevertheless, there will be intubations for patients with an expected or known difficult airway, for those needing emergency surgery, and for those needing intubation due to COVID-19 infection.

ATIs should only be performed if there is a strong indication and no other alternative is deemed safe. Coughing should be suppressed as much as possible. This can be achieved with topical anesthesia and short-acting intravenous opioids (e.g., remifentanil). Disposable devices should be used if available, and the operator should be experienced in this technique [17, 32]. Intratracheal application of local anesthetics should be avoided due to the cough stimulus [33]. Some authors recommend primarily nasal intubation via an endoscopic mask, and only switching to oral intubation in case of failure [17]. The authors of this review believe that in a complex and difficult airway management situation, using the techniques and materials one is most familiar with will be the most successful approach.

The choice of a small endotracheal tube reduces the cough generated during insertion [32]. Unfortunately, a small tube causes more resistance and therefore generates increased airway pressures. Especially for long-term mechanical ventilation of a COVID-19 patient with ARDS, it seems to be more reasonable to have a rather large endotracheal tube. Some authors suggest using an endotracheal tube size 7 or 8 for women and a size 8 or 9 for men [12]. Both indication and possible duration—a short emergency operation vs. long-term intubation—should be considered in advance. In the event of ATI failure, the ENT surgeon should decide early on whether to perform a tracheotomy [17]. Although the application of HFNCs is controversial (see above), ATI could possibly be a good indication. HFNCs may allow deeper sedation and therefore lead to less irritation and coughing.

Personal protective equipment (PPE)

In times of crisis, shortages of healthcare personnel are a central and crucial problem. Although staffing adjustments that focus on epidemiological factors may reduce this shortage [73], keeping healthcare workers healthy and safe must remain a central concern.

Availability and use of personal protective equipment is key to protecting the healthcare workforce. In general, staff members who are involved in airway management of a patient with suspected or proven COVID-19 infection should follow available recommendations. This includes correct hand disinfection and single-use airborne PPE, consisting of a mask (whenever possible N95, KN95 or filtering face piece class 2 (FFP2) or higher), protective goggles, a hat, a gown, and gloves (optionally 2 pairs); a practical overview was recently provided by Cook et al.[74]. This protective gear should be worn for all airway-related procedures, as well as while caring for COVID-19 patients [12, 13, 29] and especially during AGP.

Of equal importance is the procedure to be followed when doffing the PPE, as errors are associated with a potential risk of infection. Simulation of donning and doffing can improve safety in handling [75, 12], as can a "buddy system" with checklists followed by a specialized supervisor for donning and doffing PPE [12, 13]. At the very least, supervision of the removal process should be introduced, and proper hand hygiene after removal is mandatory [29]. Additionally, the environment should be decontaminated for at least 20 minutes [12] after AGP or depending on the air exchange capacity of the room. The virus can be detectable for up to 72 hours, depending on the surface material [20]

Pediatric airway management

Children who test positive are often asymptomatic (18-22%) or present with mild symptoms like fever and general respiratory symptoms [76, 77]. Hospitalizations and intensive care unit admissions are rare [78].

We will briefly discuss the challenges to be considered when anesthetizing children in the specific context of the COVID-19 pandemic. As in cases involving adults, protection of healthcare workers should be prioritized, with no exceptions, and PPE must be worn for all risky procedures.

There are some precautions to be taken preoperatively that could differ from the daily routine of a pediatric anesthesiologist. Because inhalational induction increases the risk of exposure to respiratory droplets and aerosols, intravenous induction should be the first choice in the case of COVID-positive children [79]. To reduce the child's anxiety as well as crying during intravenous (IV) line placement, the administration of premedication combined with patches for topical anesthesia of the puncture site is highly recommended. Because of the risk of sneezing or coughing, nasal premedication should be avoided and oral or rectal premedication should be preferred [16]. To minimize the potential risk of transmission of SARS-CoV-2 to staff and to preserve PPE, during induction the presence of parents who have close contact with the child (and are considered potentially infected) is not recommended. Nevertheless, if the parents are asymptomatic and wearing correct PPE, this may be adapted to the specific situation, because a calm child with parents is safer than an agitated, crying and coughing child[16]. The parents should leave before any aerosol-generating procedure starts.

As in the case of performing anesthesia for an adult patient, endotracheal intubation (sealing of the airway) with a VL using a modified RSI should be performed, and low-flow nasal oxygen with a conventional cannula for apneic oxygenation (e.g., 0.2 l/kg/min) should be considered during the procedure to prolong the time until desaturation and to increase safety [80]. For the same reason, due to the risk of extreme desaturation during airway management, the classical RSI technique should not be performed. In this case, the mask should be kept sealed to minimize aerosolization. To minimize the duration of intubation and the number of attempts needed, the use of apneic oxygenation should be considered and the most experienced person should perform the laryngoscopy. In addition, a cuffed endotracheal tube should be used whenever the situation allows and the weight of the child is over 3 kg. In a situation where the placement of an IV catheter is difficult and the child is agitated and combative, exposure to respiratory droplets may increase considerably. In this case, we recommend an ultrasound-guided venous puncture to facilitate venous access or an inhalational induction with the precaution of keeping the mask sealed and using the lowest possible flow rate [16]. HFNC can be useful in elective endoscopic airway surgery procedures [81], but should be carefully evaluated as it is potentially an AGP. Anesthesia can be maintained following institutional routine. Emergence from anesthesia in deep sedation is indicated to minimize dispersion of droplets due to coughing [82]; children with confirmed or potential COVID-19 should be extubated before leaving the operating room to avoid a stay in the pediatric post-anesthesia care unit [16]. Children who require a postoperative stay in the pediatric intensive care unit (PICU) should be extubated in the PICU.

In situations where a difficult airway is encountered, the principles already mentioned for the airway should be applied. In addition, task fixation and prolonged attempts at intubation should be avoided in order to avoid increased aerosolization of the virus. In children with COVID-19 the first choice for intubation is videolaryngoscopy. In case of failure, an early change to more advanced intubation techniques such as intubation via fibroscopy through SGA is desirable. In addition, even for children with COVID-19, anatomical and functional airway obstructions must be recognized and treated in order to avoid CICO situations[83, 16]. In very rare cases these situations can degenerate and a surgical airway will be required[84].

eFONA in children is very rare and is associated with poor outcomes[85]. As in adults, a surgical eFONA with scalpel is recommended: in the absence of an ENT surgeon, rapid sequence surgical tracheostomy should be preferred to access the trachea for emergencies in children under 8 years of age [86]. For children older than 8 years, we prefer a scalpel bougie technique over a needle technique [87, 88, 86]. There are no other special recommendations for changes in technique in children with aerosol-transmitted viral disease.

Developing new protection tools

The risk of exposing healthcare workers to the highly contagious SARS-CoV-2 virus and the threat of shortages of PPE pushed clinicians to develop new types of physical protection devices to use during aerosol-generating procedures. Boxes, drapes, sheets and shields made of a variety of materials (mostly plastic) were tested and used [33-37], but there was no validation and no randomized trials of these devices[89]. Systematic analyses do not recommend the use of such tools, not only due to a lack of evidence, but also because most of them have proven to be ineffective, impeding a rapid intubation through delays and making airway management unsafe [90]. In fact, the concentration of aerosol in the containment box could even be higher than without it, exposing the airway manager to a greater risk of infection [91]. Reviews published until now therefore suggest avoiding the use of protective aids and focusing more on correct handling of PPE and proper ventilation, which workers are already familiar with in their daily practice [91-93].

Airway guidelines and recommendations for the COVID-19 pandemic

Many professional societies involved in airway management promptly published consensus papers and guidelines based on expert opinions and experience from the field. The algorithms often focus on PPE and avoiding or at least reducing the duration of aerosol-generating procedures. Most of these guidelines are modifications of already existing evidence-based guidelines on airway or difficult airway management, and there remains a dearth of high-quality scientific evidence regarding the recommendations. Regardless, protecting healthcare workers is a key goal. A summary of existing airway management recommendations is presented in Table 2.

Table 2. Airway management recommendations and consensus

First author Date Country or Society	PPE	Intubation	Extubation	NIV & HFNC	eFONA & Tracheostomy	Bag Mask Ventilation & SAD	Medication	Key points
Brewster et al. *01.06.20* *Australian and New Zealand College of Anesthetists/Safe Airway Society*	PPE: minimum: impervious gown, theater hat, N95 mask, face shield, eye protection, double gloves “Buddy system”: guided by specially trained and designated staff member acting as “spotter”	RSI, Indirect VL (video screen) maximizing distance between airway and operator; Macintosh or hyperangulated blade; place the tube to correct depth; inflation of the cuff before positive pressure ventilation; viral filter to end of the tube; cuff pressure monitoring	Face mask ready; 2 staff members with PPE (same as intubation); don’t encourage the patient to cough; minimize coughing by the use of intravenous opioids, lidocaine or dexmedetomidine. Consider plastic sheets in case of coughing, place oxygen mask immediately after; oral suctioning	No evidence Should be assumed that NIV & HFNC are aerosol-generating procedures; airborne isolation rooms; protective PPE (including N95/FFP2 masks)	eFONA (CICO): Scalpel-bougie technique (to minimize the risk of high pressure oxygen insufflation via a small-bore cannula). No attempts to deliver oxygen from above during procedure (avoid aerosolization) Tracheostomy: N/A	Avoid BMV. If needed: use a vice (V-E) grip; minimize ventilation pressure through ramping and/or early use of an oropharyngeal airway with low gas flows; filter between mask and bag SAD: likely to protect better than BMV	Initial NMB: rocuronium (>1.5 mg/kg IBW) or suxamethonium (1.5 mg/kg TBW). Generous dosing for rapid onset and minimizes the risk of coughing. To avoid coughing during extubation: intravenous opioids, lidocaine or dexmedetomidine	Follow existing guidelines; modify them for COVID-19; early intubation; significant institutional preparation; principles for airway management should be same for all COVID-19 patients; safe, simple, familiar, reliable and robust practices should be adopted
Wax et al.	Fluid-resistant gown, gloves, eye protection, full face	VL; RSI; only essential team members; airborne	n/a	No evidence HFNC limited to	n/a	Bag-mask ventilation can generate aerosols (avoid when	Use of TIVA for anesthesia, avoid gas	n/a

12.02.2020 *Canada*	shield, fit-tested N95 mask, hair covers or hoods; longer sleeved gloves; consider powered air purifying respirator (PAPR); scrub suits or full coveralls under PPE; hand hygiene after PPE use; remove PPE under supervision of an infection control coach using checklist	isolation room; end tidalCO2; all exhaled gas from the ventilator should be filtered Rule out Pneumothorax in sudden respiratory deterioration (Ultrasound on bedside)		patients in appropriate airborne isolation. Avoid NIV (CPAP/BiPAP) use outside of appropriate airborne/droplet isolation. Avoid nebulization of medications		possible); filter between mask and bag		

Cook et al. *17.03.2020* *UK / Difficult Airway Society, Association of Anesthetists, the Intensive Care Society, Faculty of Intensive Care Medicine, Royal College of Anesthetists*	PPE; mask (FFP3), simple to remove; avoid complex systems; cover the whole upper body; dispose, appropriately immediately after “doffing”. “Buddy system” (observer); checklists; double-gloving for endotracheal intubation; use anti-fog for goggles/eyewear; training and practicing PPE use; negative pressure rooms with good rates of air exchange (> 12 times/h)	Specific intubation team (not part of the risk groups); most experienced airway manager; simulation; single-use equipment; rather early than late intubation; limit team to 2 persons performing intubation inside + 1 runner outside), prepare and communicate before intubation; airway strategy (primary plan and the rescue plans) avoid AGPs; good preoxygenation with sealed face mask (3-5 min), RSI, VL; intubation checklists; dedicated intubation trolley, aim to achieve first attempt success; no test of new techniques	Delayed extubation; minimize coughing; appropriate physiotherapy, tracheal and oral suction as normal before extubation; prepare for mask or low flow nasal oxygen delivery before extubation; after extubation, place a facemask; SAD may be considered as a bridge to extubation to minimize coughing; a second procedure and the possibility of airway difficulty, unlikely to be a first-line procedure; use of an airway exchange catheter is relatively contra-indicated; use drugs	No evidence HFNC recommendation debated: delays intubation, needs much O2 (empty tanks)	Scalpel cricothyroidotomy in CICO situations wearing full PPE; Closed suction	BMV: 2-handed V-E grip SGA: second generation as rescue airway also to improve seal	Intubation: Consider Ketamine 1-2 mg/kg; deep neuromuscular relaxation with rocuronium 1.2mg/kg IBW or succinylcholine 1.5mg/kg TBW Extubation: dexmedetomidine, lidocaine and opioids	Safe, accurate and swift airway management

			to suppress coughing					
Sorbello et al. *27.03.2020* *Società Italiana di Anestesia Analgesia Rianimazione e Terapia Intensiva* *European Airway Management Society*	PPE: PAPR, with helmet, protective total body suite, double gloves; If no PAPR available: goggles/face shield, FFP3/2 or N95 mask, waterproof gown, overshoes; Dedicated donning/doffing area	Preoxygenation with or without CPAP and PEEP; RSI technique; Nasal O2 1-3 L/min during apnea; VL (with separate screen) + introducer; second generation SDA if failed intubation; Early cricothyroidotomy if	n/a	NIV, HFNC should not delay an early elective intubation	Cricothyrotomy in CICO situations	Avoid BMV SADs only as rescue, 2nd generation to intubate through	Rocuronium 1.2 mg/kg IBW or Suxamethonium 1 mg/kg TBW	Full airborne protection for every phase of airway management; Training, planning, anticipation; Maximize first-pass attempt

		CICO; ATI only if mandatory						
Patwa et al. *23.05.2020* *All India Difficult Airway Association*	Hand hygiene Full PPE: waterproof gown, long shoe covers, a cap, goggles, a fit-tested N95 mask, double layer of gloves, and a head hood or full face shield; Correct donning and supervised doffing; covering the patient with a plastic sheet or intubation box.	Preoxygenation with a 2-hands 2 persons technique; continuous capnography (leakage monitoring); Low-flow O2 (< 5 L/min) nasal during apnea; RSI; most experienced clinician; Ventilation after cuffing Closed suction system; Consider ATI only in high selected cases with anticipated difficult airway	Same protection as for intubation; Suction only if necessary; Prevent coughing, agitation and emesis; Avoid any manipulation; Defer extubation if there are concerns	NIV and HFNC not recommended	Avoid cannula or needle cricothyrotomy with jet ventilation Surgical cricothyrotomy in case of complete failure of ventilation	Avoid BMV Consider surgery with SAD if safe, or awakening the patient with SAD in place	Suxamethonium or rocuronium for anesthesia induction	Modified AIDAA algorithm for airway management during COVID-19 pandemic
Al Harbi et al. *17.04.2020* *Saudi Anesthesia Society*	Hand hygiene Disposable N-95 masks, goggles, footwear, water-proof gowns and gloves (consider double glove technique); PAPR for high-risk	Intubation by the most experienced clinician; Standard ASA monitoring; VL (single-use blade); Ventilation after inflation of the cuff; Lowest gas flow	n/a	n/a	n/a	n/a	n/a	Adherence and correct usage of PPE; Ad interim Guideline (COVID pandemic still outbreaking)

	AGP.	acceptable						
Matava et al. *13.04.2020* *Society for Pediatric Anesthesia's Pediatric Difficult Intubation Collaborative / Canadian Pediatric Anesthesia Society*	Not specified PPEs; teams reduced to the minimum to preserve PPE, importance of correctly donning/doffing PPEs (with coaches). High risk clinicians should not be involved.	RSI, VL; Parents may be present until airway management.	Deep sedation (see medication) to avoid coughing Closed suction system Extubation in the OR	HFNC to be avoided if possible	n/a	Avoid BMV and Mask Induction Consider 2nd generation SADs (good seal, low airway pressures).	Premedication not nasal, oral or rectal should be preferred Consider dexmedetomidine, TIVA for extubation	Protection of healthcare workers is priority; adapt guidelines to institutional protocols
Chen et al. *29.07.2020* *Chinese Society of Anesthesiology / Chinese Association of Anesthesiologists*	Hospital scrubs inside and protective coveralls outside; medical protective mask, disposable surgical cap, goggles/face shield; wear disposable medical latex gloves and boot covers.	Airway team (experienced), patient's mouth covered with two wet gauze during preoxygenation, RSI, VL or Bronchoscope/Fiberscope (airway manager is familiar and brings distance to the airway), filter between tube, no auscultation	n/a	If patient under HFNC or NIV before intubation use caution for aerosol and droplets	n/a	Two wet gauzes, rather avoid BMV	Consider midazolam 2-5mg, etomidate 10-20mg, propofol (if stable), succinylcholine 1mg/kg, if rocuronium have sugammadex nearby for a CICO	Protection of healthcare workers

		Respirator only for COVID-19 patients after use even with filter or need to be disinfected; closed suction system						

Abbreviations: AGP: aerosol-generating procedure; ASA: American Society of Anesthesiologists; ATI: awake tracheal intubation; CICO: “can't intubate, can't oxygenate”; CPAP: continuous positive airway pressure; eFONA: emergency front-of-neck airway; HFNC: High-flow nasal cannula; IBW: ideal body weight; NIV: non-invasive ventilation; NMB: neuromuscular blockade; OR: operating room; PAPR: powered air-purifying respirator; PEEP: positive end expiratory pressure; PPE: personal protective equipment; RSI: rapid sequence induction; SGA: supraglottic airway device; TBW: total body weight; TIVA: total intravenous anesthesia; VL: video laryngoscopy; WHO: World Health Organization.

Summary

In order to further improve safety during airway management, it is important to clearly define an aerosol-generating procedure (AGP), how much aerosol is produced during one, how performing an AGP affects healthcare workers, and how much workers are put at risk of infection. A range of measures are under consideration for use in treating COVID-19 patients, among them proper hand hygiene and correct donning and doffing of PPE; simulation training for airway management involving PPE; the use of highly experienced "Airway teams" in which the person with the most experience performs the procedure; preparation for situations with an unexpected difficult airway; and suppression of coughing in patients undergoing airway-related procedures.

It is important to protect both high risk patients and healthcare workers and not to experiment with new techniques and tools that could lead to increased exposures. As was true before the onset of COVID-19, any AGP without strong indications should not be performed.

The care of COVID-19 patients is challenging due to many factors, not the least the reduced capacity of beds, ventilators, and personnel. Institutional requirements and resources need to be evaluated before the airway management starts. Triage adapted to the individual institution and situation is useful and should be discussed in advance, especially in times of low capacity. Overall, preparation and planning are even more essential.

In this review we discuss the management of the airway and the precautions that need to be taken in detail, but just as important is the realization that our knowledge will evolve over time as we learn more about the COVID-19 virus. The pandemic is ongoing, and we will be confronted with it for a while.

Practice Points

- There is limited evidence for the impact of aerosol-generating procedures and their influence on infection in healthcare workers;

- Airway preparation and management should be performed by experienced staff who do not belong to a high risk group;
- To avoid or suppress coughing in COVID patients, use a deep neuromuscular block and rapid-sequence induction for intubation and airway management;
- Hand disinfection and adequate PPE with a "buddy system" are essential for the protection of healthcare staff;
- Adapt and use algorithms and equipment that healthcare workers are already familiar with;
- Use simulation training—especially for airway management and usage of PPE—to improve adherence and safety.

Research Agenda

- Define an aerosol-generating procedure (AGP),
- Better estimate how much aerosol is produced during an AGP,
- How performing an AGP affects healthcare workers,
- How much workers are put at risk of infection during AGP procedures,
- Most effective ways to protect healthcare workers

Conflicts of Interest

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DECLARATION OF COMPETING INTEREST

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