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REVIEW ARTICLE

Aligning difficult airway guidelines with the anesthetic COVID-19 guidelines to develop a COVID-19 difficult airway strategy: a narrative review

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Abstract

The coronavirus disease 2019 (COVID-19) pandemic is caused by a coronavirus that is transmitted primarily via aerosol, droplets or direct contact. This may place anesthetists at higher risk of infection due to their frequent involvement in aerosol-generating airway interventions. Many anesthethetic COVID-19 guidelines have emerged, whose underlying management principles include minimizing aerosol contamination and protecting healthcare workers. These guidelines originate from Australia and New Zealand, Canada, China, India, Italy, Korea, Singapore, the United States and the United Kingdom. Hospitalized COVID-19 patients may require airway interventions, and difficult tracheal intubation secondary to laryngeal edema has been reported. Pre-pandemic difficult airway guidelines include those from Canada, France, Germany, India, Japan, Scandinavia, the United States and the United Kingdom. These difficult airway guidelines require modifications in order to align with the principles of the anesthetic COVID-19 guidelines. In turn, most of the anesthetic COVID-19 guidelines do not, or only briefly, discuss an airway strategy after failed tracheal intubation. Our article identifies and compares pre-pandemic difficult airway guidelines with the recent anesthetic COVID-19 guidelines. We combine the principles from both sets of guidelines and explain the necessary modifications to the airway guidelines, to form a failed tracheal intubation airway strategy in the COVID-19 patient. Valuing, and a greater understanding of, these differences and modifications may lead to greater adherence to the new COVID-19 guidelines.

Keywords COVID-19 · Coronavirus · Difficult airway · Airway management · Tracheal intubation

The world is now in the midst of the coronavirus disease 2019 (COVID-19) pandemic, caused by the severe acute respiratory syndrome-related coronavirus-2 (SARS-CoV-2) [1]. The virus is highly contagious with a reproductive number (R_0) of 2–3 [2]. It is predominantly spread by human-to-human transmission via aerosol, droplets or direct contact [3], and has a case-fatality rate of 3.4% [4].

Airway interventions may be required in COVID-19 patients. One review showed that 0–42% of hospitalized COVID-19 patients required tracheal intubation and mechanical ventilation [1]. Furthermore, difficulties during tracheal intubation may be encountered in these patients secondary to laryngeal edema [5]. SARS-CoV-2 may contribute to airway hyperreactivity, and its management is discussed later.

Failed tracheal intubation is associated with an increased risk of morbidity and mortality [6–10]. Many difficult airway guidelines from national anesthesia societies have therefore been published but they pre-date the pandemic, such as those from Canadian [9, 10], France [8], Germany [11], India [12], Japan [7], Scandinavia [13], the United States [14], and the United Kingdom [6]. These guidelines are based on the best level of evidence available, expert consensus opinions and national anesthesia society members' feedback on securing the airway in patients with difficult airways.

New anesthetic COVID-19 guidelines have been published. However, most only discuss tracheal intubation with important modifications to minimize virus contamination and to protect healthcare workers, but do not discuss an

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airway strategy should tracheal intubation fail [1, 15–19]. Others only include a brief description on the role of the supraglottic airway for rescue ventilation [20, 21]. Others briefly discuss an airway strategy after failed tracheal intubation [22–24] or one that follows previously published DAS guidelines [25]. Our article identifies and compares pre-pandemic difficult airway guidelines with the recent anesthetic COVID-19 guidelines. We combine the principles from both sets of guidelines, and explain the necessary modifications to the airway guidelines, to form an airway strategy to manage the failed tracheal intubation in the COVID-19 patient.

Difficult airway guidelines

We obtained difficult tracheal intubation guidelines by performing a PubMed database search for peer-reviewed English language articles published between 01 January 2010 and 01 January 2020. We used the search terms ('anesthesia' OR 'anesthesiology' OR 'anesthesia' OR 'anesthesiology") AND (''guidelines') AND ('airway' OR 'intubation'). This resulted in 692 articles. We extracted guidelines or consensus statements on adult difficult tracheal intubation from anesthetic societies. We excluded articles pertaining to out-of-theater or pre-hospital settings (2 articles) and those related to obstetric patients (2 articles) and critical care/intensive care patients (3 articles). The remaining nine articles were from the Canadian Airway Focus Group (CAFG) [9, 10], France's Société Française d'Anesthésie et de Réanimation (SFAR) [8], the German Society for Anesthesiology and Intensive Care Medicine (DGAI) [11], the All India Difficult Airway Association (AIDAA) [12], the Japanese Society of Anesthesiologists (JSA) [7], the Scandinavian Society of Anesthesiology and Intensive Care Medicine (SSAI) [13], the American Society of Anesthesiologists (ASA) [14] and the United Kingdom's Difficult Airway Society (DAS) [6]. These are henceforth collectively termed the 'airway guidelines' (Table 1). Extubation following difficult tracheal intubation is beyond the remit of this article, and is not discussed.

In one large database, less than 2% of registered cases were difficult tracheal intubations, and yet 93% of these were unanticipated [26]. As such, clinicians who perform tracheal intubation must have pre-planned airway strategies, and be trained and be competent in the airway devices and techniques involved in difficult airway management. Most of the airway guidelines discuss either the unanticipated [6, 7, 9, 12, 13] or both the unanticipated and anticipated difficult airway [8, 11]. Two of the airway guidelines focus on the anticipated difficult airway [10, 14].

For the unanticipated difficult tracheal intubation, the airway guidelines formulate an airway strategy based on a sequential series of plans that may be generalized as follows (see Table 1). Plan A is face mask ventilation and tracheal intubation, including considerations regarding patient positioning, preoxygenation and rapid sequence tracheal intubation [6]. Plan B is supraglottic airway insertion and ventilation to maintain oxygenation. Plan C is face mask ventilation. The order of plan B and C is interchangeable depending on the guideline and the clinical circumstances. For simplicity and based on the principle of minimizing aerosol generation for the COVID-19 patient, our article will allocate plan B as supraglottic airway ventilation and plan C as face mask ventilation. Plan D is performing an emergency front-of-neck access (FONA) to manage the resulting "cannot intubate, cannot oxygenate" scenario. The JSA guidelines uses a traffic signal system to indicate the level of patient risk with green indicating a safe condition, yellow for a semi-emergency condition, and red for a critical emergency condition [7]. These latter guidelines are still consistent with a plan A, B, C, D strategy. The latter is an educational tool but also acts as a cognitive aid for difficult airway management. Failure of each airway plan should be followed by early declaration of failure, calling for expert help, and preparation and implementation of the subsequent airway plan.

COVID-19 anesthesia guidelines

We conducted an electronic search in the PubMed database on 01 June 2020, for all English language articles published between 01 January 2020 and 30 May 2020. The following search terms ('anesthesia' OR 'anesthesiology' OR 'anesthesiologist' OR 'airway') AND ('guidelines' OR 'statement' or 'recommendations') AND ('coronavirus' OR 'SARS-CoV-2' OR 'COVID-19') were used. 189 articles were retrieved. Both authors assessed the abstracts of identified articles, and selection was by consensus according to relevance (i.e. comprehensive guidelines on adult tracheal intubation). Twelve international anesthetic COVID-19 guidelines and publications (henceforth collectively termed 'COVID-19 guidelines') were included (Table 2) [1, 15–25]. They originate from a diverse group of countries: Australia and New Zealand [22], Canada [16, 17], China [19, 24], India [20], Italy [23], Korea [15], Singapore [18], United Kingdom [25], United States [1], and an international collaboration from a clinical data set from China [21]. Most discuss the perioperative management [1, 15, 17–20, 23], whilst a few focus on airway management [16, 21, 22, 24, 25]. The airway recommendations are based on extrapolation of data and practices from previous transmissible disease outbreaks or pandemics [27–32], limited clinical COVID-19 anesthetic airway related data [21], and individual and consensus expert opinion [1, 15–25].

Table 1 Comparison of unanticipated difficult airway guidelines and a summary of the COVID-19 guidelines [6–9, 11–13, 15–25]

	Canadian CAFG 2013 [9]	French SAFR 2018 [8]	German DGAI 2015 [11]	Indian AIDDA ISA 2016 [12]	Japanese JSA 2014 [7]	Scandinavian 2010 [13]	United Kingdom DAS 2015 [6]	COVID-19 guidelines 2020 [1, 15–25]
Patient assessment and preparation	Not applicable as guidelines relate to the unconscious or induced patient	Airway assessment recommended	Assess for history and clinical predictors of difficult airways	Airway assessment recommended	"Pre-anesthetic airway assessment should be performed for each patient who will undergo anesthesia"	Airway assessment recommended	"Every patient should have an airway assessment before surgery" "Mechanical drainage by nasogastric tube should be considered in order to reduce residual gastric volume in patients with severely delayed gastric emptying or intestinal obstruction"	Assessment can be challenging due to urgency, infection control measures such as wearing PAPR making communication and auscultation difficult Care since nasogastric tube insertion is an AGP (consider placing after intubation is completed and ventilation established safely)
Personal protective equipment for airway manager and staff	No statement	No statement	No statement	No statement	No statement	No statement	No statement	Appropriate and checked Minimum: gown, glove, mask (N95/PAPR) and eye protection Buddy system for donning and doffing Careful disposal
Plan A: Tracheal intubation after induction of anesthesia								
Patient positioning	No recommendation	Sitting or head up in obese patients	Elevated upper body	Head up, or ramped in obese patients	Ramp position; Reversed Trendelenburg or sitting position in obese, parturient, and currently hypoxemic patients	Head up in obese patients	45° head up or ramped-up in obese to delay onset of hypoxia, improves direct laryngoscopy, improves airway patency and facilitates passive apneic oxygenation	45° head up or ramped-up in obese

Table 1 (continued)

	Canadian CAFG 2013 [9]	French SAFR 2018 [8]	German DGAI 2015 [11]	Indian AIDDA ISA 2016 [12]	Japanese JSA 2014 [7]	Scandinavian 2010 [13]	United Kingdom DAS 2015 [6]	COVID-19 guidelines 2020 [1, 15–25]
Preoxygenation	Not applicable as guidelines relate to the unconscious or induced patient	Achieve end-tidal oxygen fraction 0.9 using spontaneous ventilation 2–5 min, or 4 to 8 vital capacity breaths Including non-invasive ventilation, trans-nasal humidified high-flow oxygen or high-flow nasal oxygen	All patients, with a tight-fitting face mask for 3–4 min or 8 vital capacity breaths in 60 s Non-invasive ventilation	Tight fitting face mask for 3 min. If leak with face mask, then 5 min; Achieve end-tidal oxygen fraction > 0.9 Use 10 L/min, CPAP, pressure support ventilation "Strongly recommend" Nasal oxygen 15 L/min, or high flow nasal oxygen at 70 L/min	"A 3-min inhalation of a high concentration of oxygen with a fitted facemask" 'Non-invasive positive pressure ventilation can be used in obese patients and in hypoxic or critically ill patients"	Tidal volume 3 min or 8 deep breaths over 60 s	All patients "should be pre-oxygenated" 100% oxygen via effective face mask seal to achieve end-tidal oxygen fraction 0.9 (no duration stated) Can use nasal O_2 up to 15 L/min, trans-nasal humidified high flow nasal O_2 up to 70 L/min	All patients preoxygenated 100% oxygen via tight-fitting mask for 5 min Low flow nasal O_2 controversial Avoid high flow O_2 and non-invasive ventilation (if used, then place gauze over mouth and nose)
Facemask ventilation			Avoid if high risk of aspiration	"Soon after induction and also between attempts at [tracheal] intubation"	Either before or after tracheal intubation attempts	Face mask ventilation < 20 cm H_2O	"Mask ventilation with 100% oxygen should begin as soon as possible after induction of anesthesia'	Avoid as aerosol generating procedure
Rapid sequence induction	No statement regarding indication	In emergency context or if patient has full stomach	In patients with risk of aspiration	No statement regarding indication	No statement regarding indication	"Rapid sequence [tracheal] intubation is considered the safest method'. Cricoid pressure not mandatory	Aim: "greatest protection against aspiration" and avoid "need for bag-mask ventilation" Recommended if at risk of aspiration; cricoid pressure routine and to "prevent gastric distension during mask ventilation"	Aim: rapid onset to minimize risk of coughing and need for face mask ventilation Recommended for all cases; generally, cricoid pressure if indicated (high risk of aspiration) Avoid FMV

Table 1 (continued)

	Canadian CAFG 2013 [9]	French SAFR 2018 [8]	German DGAI 2015 [11]	Indian AIDDA ISA 2016 [12]	Japanese JSA 2014 [7]	Scandinavian 2010 [13]	United Kingdom DAS 2015 [6]	COVID-19 guidelines 2020 [1, 15–25]
Neuromuscular blocker	Consider neuromuscular blockade if failed oxygenation or CICO scenario	Succinylcholine or rocuronium "Depth of anesthesia and muscle relaxation to facilitate mask ventilation and tracheal intubation"	Succinylcholine or rocuronium	Succinylcholine or rocuronium	No statement	Succinylcholine preferred over rocuronium	To abolish laryngeal reflexes, increase chest compliance and facilitates FMV Succinylcholine or rocuronium Rocuronium (immediate reversal with sugammadex possible)	Rapid onset paralysis for early intubation, avoid coughing and the need for FMV Succinylcholine or rocuronium
Laryngoscope	Direct or videolaryngoscope	Videolaryngoscope if FMV possible and has at least two criteria of difficult tracheal intubation VL not supported in RSI	Direct or videolaryngoscope, or flexible or rigid bronchoscope	Direct or videolaryngoscope	"Does not recommend specific intubation devices"	No statement	"All anesthetists should be skilled in the use of a videolaryngoscope" Based on operator's experience and training	Videolaryngoscope first choice for intubation
Tracheal intubation	Maximum 3 attempts—"only if a different tactic is used and there is a reasonable expectation of success"	Maximum 2 attempts "In cases of stridor associated with respiratory distress, tracheotomy should be first line management"	Maximum 2 attempts with direct laryngoscopy	"Attempts should be limited to the minimum and repeated only if the oxygen saturation is ≥ 95%"	"Attempts should not be repeated more than twice for each anesthesia provider and for each airway device, particularly for direct laryngoscopy"	No statement on maximum number of attempts	Limited to 3 + 1 attempts (4th attempt by experienced colleague) Correct placement by "visual confirmation… bilateral chest expansion, and auscultation and capnography" No statement about leak check or cuff pressure	Most experienced/skilled airway manager Intubation is an AGP, therefore minimize attempts Auscultation may be ineffective if wearing PAPR Avoid cuff leak, inflate the cuff with air to a measured cuff pressure of 20–30 cm H_2O If using high airway pressures, ensure cuff pressure ≥ 5 cm H_2O above peak inspiratory pressure
Tracheal tube	No statement	No statement	No statement	No statement	No statement	No statement	Smaller tube preferred	Tracheal tube with subglottic suction

Table 1 (continued)

	Canadian CAFG 2013 [9]	French SAFR 2018 [8]	German DGAI 2015 [11]	Indian AIDDA ISA 2016 [12]	Japanese JSA 2014 [7]	Scandinavian 2010 [13]	United Kingdom DAS 2015 [6]	COVID-19 guidelines 2020 [1, 15–25]
Plan B: Rescue ventilation								
Device or technique	FMV or SGA FMV performed before or between attempts at tracheal intubation, two handed technique	FMV	FMV	SGA Maximum 2 attempts. Intubation—blind via intubating LMA, or under direct vision using flexible bronchoscope	FMV "Two-handed FM ventilation with a pressure-controlled ventilator"	SGA	SGA "Opportunity to stop and think about" subsequent airway interventions Second generation SGA have "greater efficacy" and "offer greater protection against aspiration than first-generation devices"	SGA Better seal than FMV (less aerosolization) but may be considered an AGP Second generation SGA due to higher seal pressure (less aerosolization) and one allows bronchoscopy intubation
Plan C: Alternative rescue ventilation								

Table 1 (continued)

	Canadian CAFG 2013 [9]	French SAFR 2018 [8]	German DGAI 2015 [11]	Indian AIDDA ISA 2016 [12]	Japanese JSA 2014 [7]	Scandinavian 2010 [13]	United Kingdom DAS 2015 [6]	COVID-19 guidelines 2020 [1, 15–25]
Device or technique	SGA	Intubating laryngeal mask	SGA	FMV	SGA	No statement	FMV	FMV
	SGA may also provide "successful rescue oxygenation in failed oxygenation/CICO scenarios"		Blind or flexible bronchoscopic tracheal intubation Return to spontaneous breathing should be considered, or further attempts at securing the airway	Complete neuromuscular blockade to ensure "best chance for optimizing mask ventilation and also create good operating conditions for cricothyroidotomy"	If not done so, administer full neuromuscular blockade. If difficult FMV continues despite full neuromuscular blockade, then consider restoration of spontaneous ventilation and consciousness		Final attempt at oxygenation Optimization: Two-person, four-handed technique Use of adjuncts e.g. oral or naso-pharyngeal airway Airway maneuvers: chin lift, jaw thrust	Avoid if possible as FMV is a AGP If required, then: Minimize leak Two-handed technique Use filter including self inflating bags Pack gauze in mouth in edentulous patients Minimize airway pressure Head up Use of adjuncts e.g. oral airway Low flow Small tidal volumes/pressure control ventilation Full muscle paralysis Use end-tidal O2 monitoring to guide when to stop FMV (once optimal oxygenation achieved)
Plan D: Front-of-neck access								

Table 1 (continued)

	Canadian CAFG 2013 [9]	French SAFR 2018 [8]	German DGAI 2015 [11]	Indian AIDDA ISA 2016 [12]	Japanese JSA 2014 [7]	Scandinavian 2010 [13]	United Kingdom DAS 2015 [6]	COVID-19 guidelines 2020 [1, 15–25]
	"Percutaneous needle-guided wide-bore cannula or an open surgical technique, governed by operator preference and equipment availability" Neuromuscular blockade should be "considered to address possible laryngospasm and facilitate face maskventilation"	Cricothyroidotomy or tracheostomy [no further details provided]	"Evidence-based recommendation of the optimal technique for cricothyrotomy cannot be given"	Continue nasal oxygen insufflation "We recommend performance of any cricothyroidotomy technique based on the familiarity of the anesthesiologist and the availability of equipment"	"When the [cricothyroid] membrane is palpable from the skin, the use of commercially available needle cricothyroidotomy kits is recommended", otherwise perform surgical cricothyroidotomy	No statement	Surgical cricothyroidotomy preferred Full muscle paralysis "Oxygen (100%) should be applied to the upper airway throughout, using a SGA, a tightly fitting face mask, or nasal insufflation"	Surgical cricothyroidotomy mostly preferred although others offer either technique depending on training Full muscle paralysis For surgical tracheostomy: Surgical tracheostomy safer than percutaneous tracheostomy Consider advancing tracheal tube and cuff safely below the intended tracheotomy site and hold respirations while incising trachea Use cuffed, non-fenestrated tracheostomy tube Avoid: Positive pressure from above Nasal insufflation Avoid diathermy and open suction (both AGPs)

AGP Aerosol generating procedure, *COVID-19*: Coronavirus disease 2019, *DAS* Difficult Airway Society, *FMV*: face mask ventilation, *FONA* front-of-neck access, O_2 oxygenation, *PAPR* powered, air-purifying respirator, *PPE* personal protective equipment, *RSI* rapid sequence induction, *SGA* supraglottic airway

Table 2 Summary of airway management guidelines for COVID-19 (see main text for full details) [1, 15–25]

	Australia/New Zealand [22]	Canada [16, 17]	China [19, 24]	India [20]	Italy [23]	Korea [15]	Singapore [18]	UK [25]	US [1]	International consensus [21]
Personal protective equipment Donning/Doffing	N95, gown, eye protection, face shield, gloves Double gloves for airway management	N95, gown, eye shield, hood/hat, gloves (PAPR controversial) Double gloves for airway management	N95/PAPR, gown, goggles/face shield, hood Double gloves for airway management	N95, gown, eye shield, cap, shoe covers Double gloves	N95, gown, face shield/goggles, loves, shoe covers Double gloves for airway management	N95/PAPR, gown, face shield/goggles, shoe covers Double gloves	N95, gown, eye protection, PAPR Double gloves considered	Full personal protective equipment Double gloves for intubation	N95/PAPR, gown, goggles/face shield, cap Double gloves for intubation	N95/PAPR, goggles, gown, hood/face shield, shoe covers Double gloves for intubation
	Buddy system	–	Buddy system	–	Buddy system	–	–	Buddy system	–	Buddy system
Operating theatre	Designated area, negative pressure room	Isolation/negative pressure room	Designated area, negative pressure room	Designated area	Designated area, negative pressure room	Negative pressure room	Isolation/negative pressure room	Negative pressure room	Designated area, negative pressure room	–
Communication	Pre-briefing; cognitive aids, checklist	–	–	–	Team briefing; cognitive aids, checklist	–	Team briefing; coordinator	Team briefing; cognitive aids, checklist	Team briefing	–
Airway manager	Most skilled/experience	Most skilled	Experienced, assisted by 2nd clinician	Experienced	Most skilled and experienced	Most experienced	Most experienced	Most appropriate	Most experienced	Most skilled 2nd operator assisting
Personnel	Limit numbers	Limit numbers	Limit numbers	Limit numbers	Limit numbers	–	Limit numbers	Limit numbers	Limit numbers	–
Preoxygenation	100% oxygen for 5 min No HFNO	100% oxygen for 5 min	100% oxygen for 5 min If HFNO, cover nose and mouth with wet gauze	100% oxygen for 5 min Cover patient's nose and mouth with wet gauze	100% oxygen for ≥ 3 min Apneic O_2 low flow	100% oxygen for 5 min No HFNO	Well-fitting mask Avoid non-invasive ventilation and HFNO	100% oxygen for ≥ 3 min, well-fitting mask No HFNO	100% oxygen for 5 min	100% oxygen for 5 min
Position	45° head up	–	Ramping in obese	–	–	–	–	Ramping in obese	–	Head up
Drugs	Succinylcholine or rocuronium	Rocuronium	Succinylcholine or rocuronium	Succinylcholine	Succinylcholine or rocuronium	–	–	Succinylcholine or rocuronium	Rocuronium	Rocuronium
Induction	Rapid sequence induction; consider cricoid pressure carefully	Rapid sequence induction ± cricoid pressure	Rapid sequence induction	Rapid sequence induction	Rapid sequence induction; consider cricoid pressure carefully	Rapid sequence induction with cricoid pressure	Rapid sequence induction	Rapid sequence induction	Rapid sequence induction with cricoid pressure	Modified rapid sequence induction
Tracheal intubation	Video laryngoscope	Consider video laryngoscope	Video laryngoscope/bronchoscope	Video laryngoscope	Video laryngoscope	Consider video laryngoscope	Video laryngoscope	Video laryngoscope	Video laryngoscope	Video laryngoscope

Table 2 (continued)

	Australia/New Zealand [22]	Canada [16, 17]	China [19, 24]	India [20]	Italy [23]	Korea [15]	Singapore [18]	UK [25]	US [1]	International consensus [21]
Supraglottic airways	Intubation preferable to SGA. SGA preferable to FMV Use 2nd generation –	Intubation preferable to SGA. SGA preferable to FMV – For airway rescue	– Use 2nd generation For airway rescue	– – For airway rescue	– Use 2nd generation For airway rescue	SGA preferred to FMV – –	Intubation preferred to SGA – –	SGA preferred to FMV Use 2nd generation For airway rescue	SGA preferred to FMV – –	Should be available – –
Face mask ventilation	Minimize ventilation pressures	If indicated, small tidal volumes	As backup option	Avoid	If indicated, small tidal volumes	If indicated, small tidal volumes	If indicated, small tidal volumes	If indicated	If indicated, small tidal volumes	Mask ventilation after induction
Front of neck access	Scalpel-bougie Avoid concurrent positive pressure ventilation from above	–	Surgical or percutaneous cricothyroidotomy	–	Surgical or percutaneous cricothyroidotomy preferred Awake tracheostomy under local anesthesia	–	–	Surgical cricothyroidotomy preferred Needle cricothyroidotomy may be appropriate	–	–
Awake intubation	–	Avoid flexible bronchoscopic intubation; consider video laryngoscope Beware inadequate sedation	Adequate sedation and topicalization; nasal route preferred Consider endoscopic mask with flexible bronchoscope	Avoid	If indicated Video laryngoscope faster than flexible bronchoscopy	If indicated	Avoid	Flexible bronchoscopy techniques unlikely to be first choice	If indicated	If indicated
Extubation	Minimize coughing: local anesthesia, dexmedetomidine, opioids Oxygen mask	–	Two layers of wet gauze to cover the patient's nose and mouth	Prophylactic antiemetics	–	–	Antiemetics Nasal prong and surgical mask over	Minimize coughing: local anesthesia, dexmedetomidine, opioids Nasal prong and surgical mask over	Prophylactic antiemetics Minimize coughing: local anesthesia, dexmedetomidine, opioids	–

FMV: face mask ventilation; HFNO: high flow nasal oxygen; PAPR: powered air purifying respirators; SGA: supraglottic airway device; –: refers to no statement from respective guidelines

Principles of COVID-19 anesthetic management

The COVID-19 airway guidelines are based on a “safe, accurate, swift” performance [25]. This involves using the most appropriate ‘airway managers’ who are “all those who manage the airway” [25] with airway interventions such as tracheal intubation, face mask ventilation and supraglottic airway insertion. They include, but are not limited to, anesthetists, intensivists and emergency department physicians. Airway managers should undertake airway techniques that are familiar and reliable, and in which they have been trained [25]. The number of staff present during aerosol generating procedures should safely be at a minimum to decrease the risk of healthcare worker infection [1, 16–20, 22, 25]. Some COVID-19 guidelines recommend excluding staff with risk factors for COVID-19 infection. These include staff > 60 years of age, cardiac disease, chronic respiratory disease, diabetes, recent cancer, immunosuppression or pregnancy [22, 25]. Other healthcare worker infection risk factors include high-risk department, longer duty hours, and suboptimal hand hygiene after contact with patients [33].

The airway guidelines pre-date the pandemic and provide no statements regarding aerosol generating procedures, healthcare worker protection or optimal site for airway management [6, 7, 14]. Aerosol generating procedures should be avoided or minimized (see below). All staff should wear checked and appropriate personal protective equipment (PPE). There should be prior preparation of drugs (anesthesia induction agents, neuromuscular blocking agents and, if required, vasoactive drugs) and airway equipment (for tracheal intubation and airway rescue techniques, and those from a nearby difficult airway trolley). Good communication and teamwork are essential, and these may be facilitated by the use of checklists, cognitive aids, practice drills and simulations [1, 22, 23, 34]. Airway managers should lead a ‘team brief’ before commencing the anesthetic management of the patient. The team brief is a meeting of all staff required for the case, such as the airway manager, anesthetic assistant or nurse, theatre nurses, surgeons (who may need to perform an emergency FONA), and theater attendants. A concise discussion of the airway strategy should be provided, including the intended sequence of airway plans and potential problems.

Aerosol generating procedures

Potential aerosol generating procedures are “procedures that mechanically create and disperse aerosols and procedures that induce the patient to produce aerosols” [35]. Anesthetists perform, or are involved in, many such procedures e.g. tracheal intubation, extubation, tracheostomy, suctioning, and various forms of ventilation and oxygen therapies [3]. Performing aerosol generating procedures is associated with an increased risk of virus infection. This includes tracheal intubation (odds ratio 6.6), tracheostomy (odds ratio 4.2), non-invasive ventilation (odds ratio 3.1), and manual ventilation before tracheal intubation (odds ratio 2.8) [29]. Standard infection control precautions (i.e. hand hygiene and wearing appropriate PPE) should be undertaken to minimize exposure to pathogens.

Healthcare worker protection

In China, one study reported a healthcare worker infection rate of 3.8% (63% in Wuhan) with five deaths [36]. In a study of COVID-19 patients undergoing emergency tracheal intubation, the estimated transmission rate to healthcare workers was unlikely to be > 1.5% [21]. In March 2020, the World Health Organization recommended droplet and contact precautions routinely, and airborne precautions for aerosol generating procedures in COVID-19 patients [37]. The minimum level of PPE for airway managers are a particulate respirator, eye protection, gown and gloves [25]. Some COVID-19 guidelines recommend donning a powered air-purifying respirator rather than N95 mask [15, 22] Local guidelines on PPE should be adhered but, since the risk of SARS-CoV-2 transmission during tracheal intubation is unknown, wearing powered air purifying respirators (if available) is an alternative option as it provides 2.5 to 100 times greater protection than the N95 mask [30].

Appropriate PPE use is associated with low transmission risk [38, 39]. However, complications of wearing PPE include reduced peripheral vision and fogging in the eye goggles (80%) [21] and PPE-associated headaches (in 81% of users) [40]. Wearing powered air-purifying respirators also reduce hearing acuity, and impair auscultation and communication [18]. Closed loop communication (i.e. patient repeating instructions back to the doctor) and pre-operative radiological investigations (e.g. chest X-ray) may therefore help.

Site for airway management

The COVID-19 guidelines recommend that, ideally, airway interventions should be performed in a dedicated area, and in an airborne infection isolation room or a negative pressure room [1, 15, 18, 19, 22, 23, 25]. However, this may not be possible in less equipped hospitals [20]. If required, a portable room high-efficiency particulate air filter can be added [15, 41]. It is also possible to physically convert a standard positive pressure operating theater into a negative pressure environment [42].

Airway manager

The SSAI guidelines state that anesthesia management "should be given by, or under very close supervision by, an experienced" anesthetist [13]. However, the COVID-19 guidelines recommend the airway manager be the most experienced/skilled person, and therefore be the one performing the first attempt at tracheal intubation [15–23, 25]. This is to secure the patient's airway as rapidly as possible and with the highest chance of success in order to minimize aerosol contamination and to protect healthcare workers. Experience and skill are also required to manage various COVID-19 factors [21, 34]. These include not being able to perform a thorough airway assessment due to urgency and infection control measures, patients having poor cardiorespiratory reserves, and a lack of resources. In addition, in critically ill cases, emergency tracheal intubation has been associated with cardiac arrest (2% of cases) and a risk of pneumothorax [21]. Additional assistance by another clinician to assist in tracheal intubation has been proposed [19, 21].

The number of attempts at tracheal intubation should be limited. After a failed first attempt, the airway manager should consider an alternative device or technique if a repeat attempt is indicated. Multiple attempts at tracheal intubation is associated with the risk of airway edema and trauma, and systemic complications [6, 7, 9, 43]. They also lead to delays, and decrease success, in subsequent airway interventions and to developing a "cannot intubate, cannot oxygenate" scenario [6, 7, 43]. The DAS guidelines state that "a maximum of three attempts at laryngoscopy are recommended (3 + 1)" with a permissible "+ 1" (fourth attempt) by a "more experienced colleague" [6]. The AIDDA and CAFG guidelines recommend a maximum of three attempts [9, 12]. The JSA recommend a maximum of two attempts "for each anesthesia provider and for each airway device, particularly for direct laryngoscopy" [7]. The DGAI recommends only two attempts at direct laryngoscopy [11]. The SAFR recommends a maximum of two attempts [8]. However, these represent limits and not targets. After an initial failed tracheal intubation attempt, subsequent attempts should be considered "only if a different tactic is used and there is a reasonable expectation of success" [9].

We now discuss airway management of the unanticipated difficult tracheal intubation in the plan A, B, C, D format in the COVID-19 patient. Later, we will discuss the management of the anticipated difficult airway and airway hyperreactivity.

Plan A: patient positioning, preoxygenation, initial face mask ventilation and tracheal intubation

Patient positioning

Various airway guidelines [6, 7, 11–13] and COVID-19 guidelines recommend that patients should be placed in a head up (including 45°) or ramped positions [21, 22, 25]. These improve preoxygenation and ventilation, prolongs non-hypoxemic apnea time, and facilitates face mask ventilation, direct laryngoscopy and tracheal intubation [6, 7, 44–46]. This is of particular importance in high risk groups e.g. critically ill, hypoxemic, or obese and parturient patients, where rapid and profound desaturation may occur during induction of anesthesia [6–9]. For the COVID-19 patient, it also decreases airway pressure if face mask ventilation is required. However, such patient positioning may not be adopted for various reasons. Performing tracheal intubation may be less ergonomical for some airway managers. It may require extra equipment such as elevation pillows in the obese patient, or a foot stool to obtain the optimal height for airway intervention. Plastic protective 'intubating' boxes may not be as securely positioned, so the use of plastic drapes or sheets may therefore be considered.

Preoxygenation

The airway guidelines recommend preoxygenation with 100% oxygen via a tight-fitting mask for 3–5 min [7, 8, 12–14], during 4 or 8 vital capacity breaths [8, 12–14], or until an end-tidal oxygen concentration of 90% is attained [6, 12]. Preoxygenation increases oxygen reserves and non-hypoxemic apnea time (up to 7–10 min), and allows more time for airway interventions [6, 47]. Some airway guidelines also recommend preoxygenation via non-invasive ventilation for hypoxemic patients [8, 12, 13], nasal oxygen up to 15 L/min [6], or warmed and humidified high flow nasal oxygen up to 60–70 L/min [6, 12]. High flow nasal oxygen supplementation can be continued after induction of anesthesia to provide apneic oxygenation during attempts at tracheal intubation to prolong non-hypoxemic apnea time [6, 8, 12]. Non-invasive ventilation is also used to preoxygenate patients with hypoxemic respiratory failure [21, 24].

Most of the COVID-19 guidelines recommend face mask preoxygenation with 100% oxygen via a tight fitting mask for 5 min [1, 15, 19–22, 24]. However, in patients with pulmonary disease, maximal preoxygenation may require 5 min or longer with tidal volume breathing [48]. A closed circuit should be used (anesthetic breathing circuit or a Mapleson C "Water's" circuit) rather than a bag-valve-mask which may expel virus-contaminated exhaled breath [25]. The latter may be prevented by attaching a viral filter over the mask [15, 19, 22]. Using low gas flows also minimizes airway pressure and aerosol contamination [20].

Various COVID-19 guidelines recommend to avoid low flow nasal oxygen [21, 22, 25], high flow nasal oxygen [15, 18, 20, 22, 23, 25] or non-invasive ventilation [18, 20, 25] due to the risk of aerosol generation [49]. Yet others recommend low flow nasal oxygen [23, 25]. However, in high-fidelity human patient simulators in a negative pressure room, the maximum exhaled air dispersion distances for supplemental oxygen were as follows [50]. For the nasal cannula technique with oxygen flow at 1, 3 and 5 L/min, the distances were 66, 70 and 100 cm [50]. For high flow nasal cannula with oxygen flow at 60 L/min, with the nasal cannula tightly fixed, the distance was 17 cm [50]. However, this increased to 67 cm (sideways leak) if the cannula was not tightly fixed [50]. For non-invasive ventilation via a helmet with inspiratory and expiratory positive airway pressures of 20 and 10 cm H_2O, respectively, the dispersion distances were negligible and 27 cm if used with and without a tight air cushion, respectively [50]. However, in a study in two healthy volunteers, there was no significant difference in aerosol production between either low, high flow nasal cannula oxygenation or non-invasive positive pressure ventilation [51]. Aerosol dispersion is dependent on the mode of host generation, complex flow phenomena, integrity of the oxygen cannula or mask interface, environmental conditions (e.g. presence of negative room pressure) and the presence of physical barriers [50, 52]. Due to the conflicting evidence and recommendations, it is reasonable to first attempt pre-oxygenation with a tight fitting mask and to use other supplemental oxygen therapies only if required. Carefully placing a wet gauze or surgical mask over the patient's nose and mouth (where appropriate) or over the nasal cannula has been recommended [19, 20, 24]. Other strategies to minimize the risk from aerosol contamination include staff wearing high-level PPE, and keeping patients in airborne infection isolation rooms or having negative pressure rooms where possible [1, 15, 17–19, 21–25]. Depletion of the oxygen supply due to high flow use is also a risk [25, 39].

Initial face mask ventilation and tracheal intubation

The AIDDA and DAS guidelines recommend that face mask ventilation should be performed soon after induction of anesthesia [6, 12]. The JSA recommends assessing and confirming facemask ventilation before tracheal intubation [7]. However, face mask ventilation is an aerosol generating procedure and should be avoided in COVID-19 patients. This circumvents the traditional teaching of confirming the ability to achieve face mask ventilation before administering neuromuscular blocking agents [53]. As a consequence, it minimizes the delay from induction of anesthesia and the administration of a rapid onset neuromuscular blocking agent, thus allowing tracheal intubation to be performed in the shortest time. However, in patients who are hypoxemic before or during induction, gentle face mask ventilation with small tidal volumes (as part of a 'modified rapid sequence') may be applied [6, 15, 16, 18, 21, 23–25, 34].

Difficulties in facemask ventilation may be due to leakage of ventilation gas, increased airway resistance, and reduced thoracic compliance [7]. Techniques that minimize peak airway pressures and optimize mask seal are shown in Table 2 [22, 25, 54]. Increasing gas flow to compensate for the gas leakage [7], however, may potentially generate aerosol. An anesthetic circle or Water's circuit is preferred as its bag is collapsible and can indicate a mask leak, unlike a self-inflating bag-valve-mask [22]. End-tidal oxygen monitoring allows early identification of maximal preoxygenation, indicating that further face mask ventilation is not required and should be stopped [22].

After induction of general anesthesia, tracheal intubation is generally performed after the administration of neuromuscular blocking agents. If difficulties during tracheal intubation are encountered, various airway guidelines recommend full neuromuscular blockade as it abolishes laryngeal reflexes, increases chest compliance, facilitates facemask ventilation, optimizes tracheal intubation conditions, and increases the success rate of tracheal intubation [6, 7, 9, 13]. The airway guidelines recommend rapid sequence induction in patients at risk of aspiration [6], or for emergency situations ("anesthesia that is not planned or not for elective patients") [13]. It is an "anesthesia induction technique designed to facilitate rapid tracheal intubation in patients at high risk of aspiration" [55]. However, all the COVID-19 guidelines recommend rapid sequence induction as the first-line technique for securing the airway [1, 15–25]. Their rationale differs from the airway guidelines. Tracheal intubation is an aerosol generating procedure, and therefore, a rapid time to tracheal intubation minimizes the risk of aerosolization by preventing coughing and eliminating the need for face mask ventilation. However, in patients with anticipated difficult airways (see below), an alternative airway strategy to rapid sequence induction may be more appropriate [22, 24, 25].

Tracheal intubation forms a better airway seal compared with supraglottic airways [56], and so decreases the risk of aerosolization. One study showed that, at 0.5 L/min gas flow, small leaks occurred in 12% of cases with the laryngeal mask compared with 1.7% with the tracheal tube [57]. A tracheal tube with subglottic suction should be used where possible [25]. After tracheal intubation, a cuff manometer is used to obtain the ideal cuff pressure to minimize a leak. One recommendation states that "if using high airway pressures, ensure a cuff pressure of at least 5 cm H_2O above peak inspiratory pressure" to avoid an airway leak [58].

The original use of cricoid pressure was to occlude the esophagus and prevent aspiration of gastric contents, and it was soon incorporated into rapid sequence induction [13]. Various airway guidelines recommend its use to protect the airway from aspiration, and prevent gastric distension during face mask ventilation [6, 7, 11]. Some of the COVID-19 guidelines recommend cricoid pressure [15, 16, 24]. Others instruct not to use it (unless indicated) to maximize tracheal intubation success and not to compromise ventilation [23]. Others recommend its removal if it causes problems [23, 25]. The effectiveness of cricoid pressure is controversial [13], and it is associated with complications e.g. airway obstruction, impeding supraglottic airway insertion, worse laryngoscopic glottic views, and aspiration can still occur [6, 7, 9, 11, 13]. It is reasonable to perform cricoid pressure only if it is indicated (i.e. the patient is at high risk of aspiration).

Various intravenous induction agents are used for rapid sequence induction but each have side effects [55]. Both thiopental and propofol are associated with hypotension [19, 20]. Midazolam has a slow onset of action [19, 20]. Etomidate is associated with worse intubating conditions than propofol and adrenocortical suppression [19, 20]. Ketamine is recommended in patients with an increased risk of cardiovascular instability [25, 55]. Strategies to minimize hypotension during or after tracheal intubation include administering a crystalloid bolus (if not contraindicated), reducing induction agent dose, and the use of vasopressors [21, 25]. Boluses of intravenous induction agents may be indicated during repeated attempts at tracheal intubation to prevent accidental awareness [59].

For rapid sequence induction, the SSAI airway guidelines recommend full neuromuscular blockade with succinylcholine [13], whereas other airway guidelines recommend using either succinylcholine or rocuronium [6–8, 12]. The COVID-19 guidelines recommend either succinylcholine (1 to 1.5 mg/kg) [19, 20, 22–25] or rocuronium (1 to 1.2 mg/kg) [1, 19, 21, 23–25]. Succinylcholine is used due to its short duration of action. The reason is that if tracheal intubation fails, then theoretically resumption of spontaneous ventilation will soon follow. However, in a study of apneic healthy patients who received succinylcholine 1 mg/kg, 85% of patients had a pulse oximetry reading (SpO_2) $\leq 90\%$ despite spontaneous diaphragmatic movements [60]. In critically ill patients, their oxygen reserves would be more limited as reflected in the study from Wuhan where most patients were hypoxemic before and during emergency tracheal intubation [21]. In the latter study, rocuronium was used in 99% of emergency tracheal intubations [21]. Rocuronium 1 mg/kg, although longer lasting [61], may be a better alternative than succinylcholine. First, its prolonged duration of action maintains optimal intubating conditions for longer and prevents coughing or laryngospasm [1]. Second, rocuronium has a longer non-hypoxemic apnea time than succinylcholine following rapid sequence induction [62]. Third, it can be reversed almost immediately by an appropriate dose of sugammadex [63].

Various airway guidelines do not make a recommendation between conventional direct laryngoscopy or videolaryngoscopy for tracheal intubation [6, 7, 9, 12]. However, videolaryngoscopy has been shown to be superior to direct laryngoscopy [64]. It is associated with improved laryngeal views, reduced difficult views, decreased tracheal intubation difficulty, less failed tracheal intubations with experienced operators, and decreased laryngeal/airway trauma and hoarseness [64]. It also increases the distance between the patient and the airway manager [1]. Videolaryngoscopy is therefore recommended as the first-line technique in COVID-19 patients to maximize first attempt success [17–20, 22, 23, 25].

In summary, the airway and COVID-19 guidelines recommend pre-oxygenation, either in a head up or a ramped position. Pre-oxygenation in the COVID-19 patient is best performed using a tight-fitting mask. There is conflicting evidence regarding other forms of supplemental oxygen therapy so a surgical mask should be placed over the patient's mouth and nose (if appropriate) and staff should wear appropriate PPE. The airway guidelines only recommend rapid sequence induction in patients at high risk of aspiration. However, in the COVID-19 patient, to secure the airway in the shortest time and with the highest success rate, rapid sequence induction should be performed by the most experienced/skilled airway manager using a videolaryngoscope. There is conflicting evidence on the utility of cricoid pressure, and it is reasonable to use it only in patients at high risk of aspiration. Fast onset and full neuromuscular blockade can be achieved using either succinylcholine or rocuronium. In various airway guidelines, facemask ventilation is part of plan A or performed soon after induction of anesthesia. The COVID-19 guidelines recommend that facemask ventilation should be avoided but, if needed, then ventilation using low airway pressure and small tidal volumes is recommended.

Plan B: supraglottic airway devices

After failed tracheal intubation, several airway guidelines recommend the insertion of a supraglottic airway for rescue ventilation [6, 12, 13], which is successful in 65–94% of failed tracheal intubation cases [65, 66]. Other airway guidelines recommend facemask ventilation as a plan B [7, 8, 11]. The COVID-19 guidelines recommend using supraglottic airway ventilation as there is less leak compared with using face mask ventilation [15, 22, 25]. It can therefore be used before, and in between, attempts at laryngoscopy [1, 25].

The supraglottic airway should be one that has a success rate, high seal pressure and allows flexible bronchoscopic tracheal intubation. If it is used with controlled ventilation, low airway pressure ventilation should be used and full neuromuscular blockade considered.

If supraglottic airway ventilation is successful, there are four options recommended by the various airway guidelines [6–9, 11, 12, 14]. First, continue airway management with the supraglottic airway. Second, proceed with flexible bronchoscopic tracheal intubation via the supraglottic airway [67]. Third, wake up the patient. Fourth, performing FONA (whilst ventilation is still possible) [6]. These options are now discussed further in the context of the COVID-19 patient.

In the COVID-19 patient, continuing with a supraglottic airway is not recommended if other options are available for a few reasons. First, continuing with just the supraglottic airway is considered a "high-risk option" [12] since tracheal intubation has already failed. Second, loss of airway control may occur due to airway edema (secondary to prior and repeated airway manipulations), aspiration, laryngospasm and malpositioning of the supraglottic airway. Third, supraglottic airway placement may also be considered aerosol generating due to airway leaks [3]. Leaks may occur secondary to malpositioning (in 50–80% of patients), incorrect size of device, use of high ventilation pressures, or due to laryngospasm [68]. Subsequent airway interventions e.g. face mask ventilation, may generate further aerosol.

Bronchoscopic tracheal intubation via the supraglottic airway should be considered as it has a first time success rate of 90–96% in patients with predicted difficult airways [69]. In addition, the bronchoscopic view may provide useful information on supraglottic airway positioning and airway abnormal anatomy or pathology [7]. In COVID-19 patients, tracheal intubation offers an optimal seal of the airway to prevent aerosolization. During bronchoscopic tracheal intubation, full neuromuscular blockade should be established, and positive pressure ventilation and insufflation or suction via the bronchoscope port avoided [22]. A 'closed' method of this technique has been described [70].

Waking up the patient may not be feasible. This may be due to the patient being hemodynamically unstable or hypoxemic, requiring a more definitive airway such as FONA, or where emergency surgery must proceed immediately [6, 9]. For example, in one study, almost 75% of patients requiring emergency tracheal intubation were hypoxemic during the procedure [21]. If a neuromuscular blocking agent was administered, then its reversal is required before waking up the patient. Reversal is by either spontaneous metabolism and elimination of succinylcholine, or administering the appropriate dose of sugammadex if rocuronium was used. However, reversal of neuromuscular blockade may be delayed, and does not guarantee adequate airway patency or recovery of spontaneous/adequate ventilation [6, 7]. In addition, it may also require full reversal of opioids and benzodiazepines if previously administered.

FONA during successful plan B allows a more controlled and less time-sensitive setting than if it needs to be done as plan D (in a "cannot intubate, cannot oxygenate" scenario, see below).

In summary, the airway guidelines vary in their recommendations for rescue ventilation, using either a face mask or supraglottic airway. The COVID-19 guidelines recommend supraglottic airway ventilation as it forms a better airway seal and has a high success rate. If successful, it is reasonable to use the supraglottic airway as a conduit for flexible bronchoscopic tracheal intubation as the latter has a high success rate and seals the airway to minimize aerosol contamination. Other options after successful supraglottic airway ventilation (e.g. proceeding with surgery with just the supraglottic airway in place, or waking up the patient) may not be feasible or safe to perform.

Plan C: face mask ventilation

A "final attempt at face mask ventilation" as a plan C after both failed tracheal intubation and failed supraglottic airway ventilation is recommended [6]. However, as per the COVID-19 guidelines, face mask ventilation may not have been performed previously as it is an aerosol generating procedure. Face mask ventilation at this stage may prevent or reverse hypoxemia since the patient may have been apneic during the preceding attempts at tracheal intubation and supraglottic airway ventilation. If successful, it avoids the need to perform an emergency FONA, which is invasive and rarely performed by most airway managers. In one study, after failed tracheal intubation, most cases (63.6%) were not associated with difficult face mask ventilation [71]. Gentle face mask ventilation with small tidal volumes should be applied if needed.

The AIDDA and DAS guidelines recommend that, after successful facemask ventilation as a plan C, the patient should be woken up [6, 12], "in all but exceptional circumstances" [6]. The rationale is that the airway control is now not possible by tracheal intubation and supraglottic airway ventilation. Should airway control suddenly then be lost, then the only recourse is performing an emergency FONA. However, waking up the patient has the same considerations and difficulties as mentioned above. If oxygenation is not adequate, then plan D (see below) should be initiated.

In summary, both airway and COVID-19 guidelines recommend both facemask and supraglottic ventilation as rescue ventilation techniques after failed tracheal intubation. As a plan C, if facemask ventilation is successful then the patient should be woken up in all but exceptional circumstances. If it is not successful, then plan D must be implemented immediately.

Plan D: front-of-neck access

In the event of a "cannot intubate, cannot oxygenate" scenario, the airway manager is required to perform an emergency FONA procedure (Tables 1 and 2). The CAFG and DAS airway guidelines recommend the surgical ('scalpel, bougie, tube') method of cricothyroidotomy [6, 9]. The JSA guidelines recommend cannula cricothyroidotomy if the cricothyroid membrane is palpable from the skin [7]. The AIDDA recommends choosing a technique "based on the familiarity of the anesthesiologist and the availability of equipment" [12]. The SSAI airway guidelines do not mention FONA [13]. FONA is aerosol generating since a cannula cricothyroidotomy requires high flow oxygen insufflation or high pressure jet ventilation, and a tracheostomy involves insertion or removal of a tracheostomy tube, or open suctioning through it [49]. Two COVID-19 guidelines recommend a surgical technique [22, 23]. Others recommend either cannula or surgical FONA [21, 25], dependent on training factors [25].

Once a "cannot intubate, cannot oxygenate" scenario has occurred, the CAFG and DAS airway guidelines recommend full neuromuscular blockade to optimize conditions for FONA attempts, and to relieve laryngospasm and facilitate facemask ventilation [6, 9]. The DAS guidelines also recommend that "100% oxygen should be applied to the upper airway throughout, using a supraglottic airway, a tightly fitting face mask, or nasal insufflation" [6]. However, nasal insufflation and concurrent positive pressure face mask ventilation should be avoided in COVID-19 patients to minimize aerosolization [22].

In summary, both airway and COVID-19 guidelines vary in their recommendations for emergency FONA techniques. The options include a surgical or a cannula cricothyroidotomy, but the latter may potentially cause aerosolization during oxygen insufflation or jet ventilation. The airway guidelines recommend administration of supplemental oxygen when performing FONA. However, in the COVID-19 patient, high flow oxygen and application of positive pressure should be avoided. In addition, full neuromuscular blockade should be established to reverse potential causes of the "cannot intubate, cannot oxygenate" scenario, and to facilitate airway interventions. As evidence is lacking at the moment, the choice of technique is dependent on the needs of the clinical situation, equipment availability and on the airway manager's training and familiarity.

Anticipated difficult airway in the COVID-19 patient

After a full airway assessment, airway managers may consider a patient to have an anticipated difficult airway e.g. those with a past history of failed intubation or with severe trismus, fixed cervical neck flexion or airway radiotherapy. However, predictors of difficult airways are not reliable [7, 10, 11, 26]. In one study, only 25% of anticipated difficult tracheal intubation had an actual difficult tracheal intubation [26]. The ASA, CAFG, SAFR, DGAI and JSA airway guidelines include the management of patients with anticipated difficult airways [7, 8, 10, 11, 14], but a full discussion on this topic is beyond the scope of this review.

If a patient with an anticipated difficult airway presents for surgery, an initial decision is whether surgery can be performed under local anesthesia infiltration or regional anesthesia, or if general anesthesia is required. With the latter, the likelihood, and clinical impact, of difficulties in facemask ventilation, supraglottic airway ventilation, laryngoscopy, tracheal intubation and FONA should be assessed [8, 10, 14]. This assessment then guides decision-making between various management choices (basic versus advanced airway techniques) as follows [10, 14]. First, should tracheal intubation be performed after induction of general anesthesia or in the awake patient? Second, should spontaneous ventilation be ablated (usually by neuromuscular blocking agents) or preserved? Third, should the initial tracheal intubation be attempted with direct or indirect laryngoscopy? Fourth, is a non-invasive (e.g. tracheal intubation) or an invasive (FONA) airway technique required? Finally, in rare cases, is cardiopulmonary bypass or extracorporeal membrane oxygenation required (established under local anesthesia of the femoral vessels) before the induction of general anesthesia [7, 10]? These latter techniques are considered in patients with severe tracheal compression [7, 10]. Answering these management choices helps define the best plan A.

In patients at risk of a "cannot intubate, cannot oxygenate" scenario, tracheal intubation should be performed in the awake, spontaneously ventilating patient. Awake tracheal intubation techniques include direct laryngoscopy, videolaryngoscopy, flexible or rigid tracheal intubating bronchoscopy, and FONA. Awake tracheal intubation has a high success rate with failure occurring in 1–2% of cases [72], and has various advantages in patients with anticipated difficult airways. Avoiding anesthetic induction agents preserves airway patency, protective airway reflexes, and respiratory and cardiovascular function. In addition, if the primary awake tracheal intubation technique fails, then the patient is still awake to allow a change of awake technique and for help to be obtained. Other awake tracheal intubation techniques should then be considered including awake FONA.

The COVID-19 guidelines recommend that awake tracheal intubation should be avoided unless indicated as it is aerosol generating due to potential coughing [18, 20, 25]. Sedation is used to facilitate patient cooperation and to obtund coughing. However, over sedation increases the risk of respiratory depression, airway loss, hypoxia, aspiration and cardiovascular instability [72]. These may in turn require airway interventions that are aerosol generating, e.g. face mask ventilation, tracheal intubation and emergency FONA. Airway topicalization is also required, but may cause aerosolization due to gagging and coughing. Some COVID-19 guidelines recommend avoiding atomizing, spraying or nebulizing local anesthetics [15, 16, 18, 20, 24]. Alternative options include the use of local anesthetic gels or swabs soaked in local anesthetic, or performing the appropriate nerve blocks. A surgical mask should be placed over the patient's mouth and nose where possible, and staff should wear appropriate PPE. Awake videolaryngoscopy has been recommended over flexible bronchoscopic tracheal intubation as it is faster [16, 23]. Alternatively, the latter may be performed via an endoscopic mask to minimize aerosol contamination [24].

In summary, management of the anticipated difficult airway includes a thorough assessment of the airway, although difficult airway predictors are not fully reliable. The airway guidelines require the formulation of an airway strategy, including deciding on the best plan A based on management choices between basic versus advanced airway techniques. Awake tracheal intubation or awake FONA should be considered in patients at risk of a "cannot intubate, cannot oxygenate" scenario. In COVID-19 patients, awake tracheal intubation is aerosol generating and should only be performed if indicated. However, sedation and airway topicalization may result in aerosol contamination and care must be taken to minimize this.

SARS-CoV-2 and airway hyperreactivity

The ACE2 receptor for SARS-CoV-2 is expressed on airway epithelium and lung pneumocytes [73]. Respiratory tract virus may damage the epithelium, leading to impaired tracheal smooth muscle relaxation and airway hyperreactivity [74]. The incidence and clinical significance of airway hyperreactivity in COVID-19 patients is uncertain and its management may be extrapolated from the management of asthma and bronchospasm [75]. Prophylactic measures include ensuring an adequate depth of anesthesia and administering intravenous lignocaine 1.5–2 mg/kg prior to airway manipulation [76]. Avoidance of precipitating drugs (e.g. histamine-releasing agents such as atracurium and mivacurium), and using drugs with bronchodilatory properties (e.g. sevoflurane and ketamine), should be considered [75]. Mainstay treatment includes increasing volatile agent concentration, administering steroids, intravenous ketamine or magnesium sulphate, and in refractory cases, intravenous epinephrine. Bronchodilator administration (e.g. salbutamol) is recommended via a metered-dose inhaler rather than via a nebulizer [1, 22]. The inhaler can be connected to the anesthetic breathing circuit, but clamping of the tracheal tube prior to circuit disconnection is recommended [25]. In COVID-19 patients, the use of steroids is controversial due to the concerns of possible viral replication and increased mortality secondary to pneumonia [77].

Conclusion

Airway guidelines form the basis of anesthetists' training and practice, and these include those for the unanticipated difficult airway and the anticipated difficult airway from Canada, France, Germany, India, Japan, Scandinavia, United States, and the United Kingdom. Since the advent of the COVID-19 pandemic, many COVID-19 anesthesia guidelines have been published but they either do not, or only briefly, discuss formulation of an airway strategy for the COVID-19 patient. Even though the older airway guidelines pre-date the COVID-19 pandemic, they still remain very relevant. Our narrative review identifies and explains the important modifications required to form an up-to-date airway strategy according to the principles of anesthetic COVID-19 management i.e. minimizing aerosol contamination and protecting healthcare workers.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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