Brazilian Journal of Anesthesiology 2024;74(1): 744477

Sociedade Brasileira de Anestesiologia

Brazilian Journal of ANESTHESIOLOGY

ORIGINAL INVESTIGATION

Recommendations from the Brazilian Society of Anesthesiology (SBA) for difficult airway management in adults

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Received 12 June 2023; accepted 12 December 2023
Available online 21 December 2023

KEYWORDS
Airway management;
Difficult airway;
Intubation;
Laryngoscopy;
Anesthesia;
Consensus;
Videolaryngoscopy;
Human factors;
Extubation

Abstract
Difficult airway management represents a major challenge, requiring a careful approach, advanced technical expertise, and accurate protocols. The task force of the Brazilian Society of Anesthesiology (SBA) presents a report with updated recommendations for the management of difficult airway in adults. These recommendations were developed based on the consensus of a group of expert anesthesiologists, aiming to provide strategies for managing difficulties during tracheal intubation. They are based on evidence published in international guidelines and opinions of experts. The report underlines the essential steps for proper difficult airway management, encompassing assessment, preparation, positioning, pre-oxygenation, minimizing trauma, and maintaining arterial oxygenation. Additional strategies for using advanced tools, such as video laryngoscopy, flexible bronchoscopy, and supraglottic devices, are discussed. The report considers recent advances in understanding crisis management, and the implementation seeks to further patient safety and improve clinical outcomes. The recommendations are outlined to be uncomplicated and easy to implement. The report underscores the importance of ongoing education, training in realistic simulations, and familiarity with the latest technologies available.

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https://doi.org/10.1016/j.bjane.2023.12.001

Difficult airway management during anesthesia is a major challenge for the clinician and requires a careful approach and well-designed protocols. Rapid assessment and action are mandatory in this condition, which can occur in a variety of scenarios, from elective procedures to medical emergencies.

It is, therefore, essential to underline the importance of ongoing training, education in realistic simulations and familiarity with the latest technologies available. Multidisciplinary approach and collaboration among healthcare providers, comprising anesthesiologists, surgeons, and nursing staff, play a decisive role in effective difficult airway management.

The present article aims to provide a comprehensive framework of practical recommendations for the management of patients presenting difficult airway, encompassing all steps from initial assessment to intervention strategies. By acknowledging the complexity and variability of these scenarios, the implementation of these recommendations aims to promote patient safety and improve clinical outcomes.

The present document is based on a synthesis and analysis of the current literature, mainly considering the most recent guidelines published by the American Society of Anesthesiologists (ASA),[1] and aims to assist the decision-making process during difficult airway management in anesthesiology. The Brazilian Society of Anesthesiology's (SBA) recommendations are not intended to establish absolute standards and using them cannot assure specific outcomes. The present recommendations may be implemented, adapted, or rejected according to the clinical scenario and the document can be revised as necessary to keep pace with evolving medical evidence.

Airway assessment

How to assess the airway

Before starting anesthetic care or airway management, an assessment should be performed whenever possible. There are two key issues to be observed during the clinical assessment:

- Risk assessment to predict difficult airway and risk of pulmonary aspiration: it includes checking data obtained from the patient's medical history or medical records, comprising personal data (age, sex, body mass index, weight, and height), medical conditions, diagnostic tests and interviews or questionnaires with patient/family. History of difficult tracheal intubation should be considered, as well as distorted airway anatomy, snoring, obstructive sleep apnea-hypopnea syndrome, diabetes mellitus or complementary exam findings (e.g.: plain X-ray, CT-scan).[1]

Several medical conditions can be associated with challenging airway management, such as acromegaly, congenital anomalies, rheumatoid arthritis, cardiopulmonary disease, endocrinopathies, ankylosing spondylitis, temporomandibular disorders, head/neck mass and airway lesions, obesity, pregnancy, burns, and coagulopathies with increased risk of bleeding.[2]

Airway or facial trauma, cervical spine instability, small mouth opening, small mouth, short and muscular neck, burn sequelae, congenital abnormalities, tumors, abscesses, trismus, congenital syndromes, history of difficult tracheal intubation are often associated with challenging tracheal intubation.[2]

Evaluating the risk of pulmonary aspiration is an important part of the pre-anesthesia assessment. For high-risk patients, rapid sequence induction and tracheal intubation or awake tracheal intubation may be necessary. Some factors that increase the risk of pulmonary aspiration are non-fasting, gastrointestinal obstruction, gastroesophageal reflux disease, hiatal hernia, previous gastrointestinal surgery, emergency surgery, delayed gastric emptying caused by conditions such as diabetes mellitus, chronic renal failure, opioid use, pregnancy, and obesity.[2]

- Airway examination (bedside and assisted): aims to detect upper airway disorders or anatomical anomalies by measuring facial and jaw features, anatomical distances and landmarks, obtaining ultrasound imaging, performing virtual laryngoscopy/ bronchoscopy, three-dimensional printing or bedside endoscopy.

Facial and jaw feature measurements comprise assessing mouth opening, voluntary jaw protrusion, head and neck mobility, presence of prominent incisors, presence of beard, and upper lip bite test. Anatomical measurements include modified Mallampati scores, thyromental distance, sternomental distance, interincisor distance, neck circumference, ratio of neck circumference to thyromental distance, ratio of height to thyromental distance, hyomental distance, and hyomental distance ratio.

If a difficult airway is suspected, the patient or guardian must be informed, the patient informed consent form should be carefully documented, and the airway assessment registered in the medical record. If awake tracheal intubation is the chosen management, the procedure should be explained in detail and any questions answered to gain patient collaboration during the procedure.

The assessment must be carried out for every patient even if general anesthesia is not planned. Predictive methods are unable to detect intrathoracic airway issues or hidden conditions.[2] When individually analyzed, the modified Mallampati test has limited accuracy for predicting difficult airways, thus it is not a useful screening tool. No single test reliably predicts how challenging it will be to perform mask ventilation, to accurately insert a supraglottic device, to execute direct laryngoscopy or difficult tracheal intubation. The challenge in airway management grows with the increase in the number of abnormal parameters.

Given most cases of difficult airway are unexpected, a comprehensive airway management strategy should be designed for each patient rather than a one-size-fits-all plan, even when the assessment is normal. Although difficult mask ventilation combined with difficult laryngoscopy is uncommon, it is far from rare.[3]

Predicting problems in airway management is still a defying matter, therefore it is important to always be ready for unexpected difficulties. If in doubt, direct laryngoscopy can be performed under topical anesthesia or very light sedation to assess the possibility of tracheal intubation.[3] Awake tracheal intubation has a high success rate and a favorable safety profile, but it is underused in cases of anticipated difficult airway.[4]

Federal Council of Medicine (CFM) Resolution # 2,174/2017 provides for the practice of anesthesia and knowledge of its text must be mandatory for every anesthetist working in Brazil.[5] In its Annex II, the Resolution determines that the pre-operative anesthesia documentation must describe, among other aspects, patient risk stratification, and include a specific Informed Consent Form for anesthesia and consultation or pre-anesthetic assessment form. This consent form must contain, among other items, physical examination data, including detailed airway assessment: mouth and jaw opening, Mallampati classification, atlanto-occipital mobility, thyromental distance, dental conditions, dental prosthesis, and neck circumference. The recommended fasting time is 2 hours for clear liquids without residue (water, tea); 4 hours for breast milk; 6 hours for non-human milk or formula; 6 hours for light meals; 8 hours for regular diet.[4]

Ultrasound for difficult airway assessment

Ultrasound for initial assessment of difficult airway

Recent studies suggest that the combination of taking anatomical measurements assisted by ultrasound, performing careful physical examination, and determining facial characteristics, can help identify possible candidates for difficult airway and difficult laryngoscopy.[6,7] As examples, we have the measurement of the distance from skin to the hyoid bone, tongue thickness and distance from skin to the epiglottis.[8]

Prospective observational studies have shown that a difficult airway can be anticipated by measuring both temporomandibular junction mobility and tongue thickness, in association with other predictors, supporting adequate planning and systematization of management.[9]

Preoperative upper airway ultrasound imaging as a predictor of difficult airway in adults without anatomical abnormalities suggestive of difficult laryngoscopy (Cormack-Lehane III and IV)

Despite the availability of several tests as clinical indicators of difficult airway assessment, difficult laryngoscopy can still be a major issue in anesthetic practice. Carsetti et al.[10] published a systematic review aiming to answer this matter. Among the fifteen studies selected, the large majority used distance measurements from skin to epiglottis, skin to hyoid bone, skin to vocal folds and the pre-epiglottic space depth to distance from epiglottis to vocal folds ratio (Pre-E/E-VC). The study found that patients with challenging laryngoscopy had higher scores in the first three measurements, compared to patients with straightforward laryngoscopy, and that the distance from skin to epiglottis was the most frequently studied parameter. Due to the great heterogeneity in the methods of measurements of the distances, such as different head positioning (neutral, extended, or olfactory position) and the execution of external maneuvers during laryngoscopy, we still cannot draw any robust scientific evidence from the findings of Carsetti et al.

Martinez-Garcia et al.,[11] in a prospective observational study, reported that the distance from skin to epiglottis (DSE) $\geq$ 3 cm could be associated with difficult laryngoscopy, with a positive predictive value (PPV) of 69.23 %. Equally, a difference between skin-epiglottis distance and skin-glottis distance longer than 1.9 cm (DSE − DSG $\geq$ 1.9 cm) had a PPV of 78.57%.[11]

Alessandri et al.[12] and Sotoodehnia et al.[13] described the suitability of ultrasound imaging to identify difficult airways, comprising challenging laryngoscopy and difficult mask ventilation. They revealed that the measurements correlated to difficult airway were distance from skin to epiglottis, distance from skin to hyoid bone; hyomental distance, and hyomental distance ratio.

Ultrasound for identification of the cricothyroid membrane

Anesthesiologists have found it easier to correctly identify the cricothyroid membrane by palpation guided by ultrasound.[14] Siddiqui et al.[15] reported that ultrasound is more accurate than palpation for identifying the cricothyroid membrane in subjects with poorly defined cervical reference points. Transverse laryngeal ultrasonography enables identifying inverted V-shape imaging of the thyroid cartilage with high sensitivity and interindividual agreement but with low specificity (i.e., inverted V-shape images were also viewed at the cricothyroid membrane level, potentially confounding its correct location).[16]

For ultrasound identification of anterior cervical structures, mainly the cricothyroid membrane, we can use the TACA (Thyroid cartilage—Airline—Cricoid cartilage—Airline) method. With a linear transducer placed in the transverse position on the anterior cervical region, we initially identify the triangular-shaped thyroid cartilage (T), then sliding the transducer caudally we visualize the air (A) corresponding to the cricothyroid membrane, moving the transducer further caudally, we identify the cricoid cartilage as a C-shaped structure and, finally, we move the transducer back cephalad until the cricothyroid membrane is visualized and marked. We can also identify the same structures with the transducer placed longitudinally on the anterior cervical region, in a technique called "string of pearls". With the transducer positioned longitudinally and close to the sternum, we identify hypoechoic images similar to strings or pearls (tracheal rings); sliding the transducer cephalad we visualize a more elongated, wider and more superficial structure (cricoid cartilage), then, immediately more cephalad, the cricothyroid membrane is found. Finally, further cephalad, we identify the thyroid cartilage.[17]

The cricothyroid membrane can be identified by inspection and/or palpation and, if these methods fail, the membrane can be identified by ultrasound. The technique has a quick learning curve with long-lasting retention and has been shown to be more effective than the neck palpation technique.[18] Using ultrasound for pre-anesthetic identification of the cricothyroid membrane in pregnant women is a straightforward and superior choice to computed tomography, as it is devoid of any risk of ionizing radiation to mother and fetus.[19] Additional imaging studies can be used for the correct identification and differentiation of cervical structures.

Inaccurate location of the cricothyroid membrane in "cannot intubate, cannot ventilate" situations can result in cricothyroidotomy failure and a disastrous outcome. It is sensible to identify the cricothyroid membrane before anesthesia induction as a routine pre-anesthetic assessment, especially for anticipated difficult airway patients, and it is recommended by several practical guidelines.[1,20]

Pre-oxygenation and apneic oxygenation

Pre-oxygenation in patients with difficult airway

The pre-oxygenation goal is to increase patient oxygen reserve to prevent or delay arterial oxygen desaturation during apnea. All difficult airway patients must be pre-oxygenated before general anesthesia induction and denitrogenation can be attained offering a proper 100% oxygen flow to the respiratory system while holding the mask firmly adapted to the patient's face. Pre-oxygenation is effective when the expired fraction of oxygen (EtO2) reaches 0.87 to 0.9.[21] Several pre-oxygenation techniques have been described, two of which are widely used[21]:

- Spontaneous ventilation with 100% O2 for 3 to 5 min using a fresh gas flow rate of 5 $L.min^{-1}$ in the breathing circuit;
- Spontaneous ventilation with 4 to 8 vital capacity maneuvers with 100% oxygen, for 30 and 60 s, respectively.

Nasal apneic oxygenation can be delivered by high-flow oxygen (10 to 15 $L.min^{-1}$) through nasal cannulas and has been shown to significantly delay the onset of desaturation during apnea (safe apnea time) until definitive airway control. The technique has prolonged safe apnea time in the operating room, pre-hospital care and emergency room.[22] An alternative approach for preventing hypoxia during induction and rapid sequence intubation is to avoid apnea altogether. An extensive multicenter study showed that gentle mask ventilation between induction and laryngoscopy reduced the incidence of hypoxia without adversely affecting pulmonary aspiration rates.[23]

Although efficacy data are limited for the non-obese population, pre-oxygenation should be used during the induction of general anesthesia in obese patients, as it enables higher safe apnea time without being harmful to the patient. Desaturation can occur between 19% and 70% of tracheal intubations and it is the most common cause for aborting the first tracheal intubation attempt. Thus, using pre-oxygenation and apneic oxygenation in all patients is a sensible measure. Standard or modified larger caliber nasal cannulas for administration of gas flow rates between 10 and 15 $L.min^{-1}$ are well tolerated, low-risk and a low-cost alternative for patient oxygenation.[22]

Proper patient positioning during pre-oxygenation is important, as a moderate (approximately 25°) head-up position can delay desaturation onset in the general population. In obese patients, controlled studies have also shown the benefit of sitting or the 25-degree head-up position during pre-oxygenation compared to the supine position.[24]

The administration of supplemental oxygen is recommended prior to initiating difficult airway management and, whenever possible, during the difficult airway management process, including tracheal extubation. Opportunities for supplemental oxygen administration include (but are not limited to) delivery of oxygen via nasal cannulas, face mask, or supraglottic insufflation.[1] According to the Difficult Airway Society, administration of supplemental oxygen is also recommended for awake tracheal intubation.[4] Administration of supplemental oxygen should start upon patient arrival in the operating room and continue throughout the preparation for awake tracheal intubation. If available, oxygen administered via a high-flow nasal cannula (HFNO) should be the technique of choice.[4]

Other methods can be considered, especially for critically ill patients. Non-invasive positive pressure ventilation (NIPPV) delivers a high concentration of oxygen, alleviates respiratory muscle fatigue, recruits atelectatic alveoli, and can be used before definitive control of the airway. For patients who do not tolerate the face mask, a supraglottic device can be used to increase oxygenation or to provide a conduit for tracheal intubation.[22]

Awake tracheal intubation

Sedation goals during awake tracheal intubation

Sedation during awake tracheal intubation aims to offer comfort and increase patient cooperation, making the procedure easier, safer, and more tolerable, ensuring optimal conditions for intubation when associated with effective topical anesthesia.[4,25] Sedation should be minimal, promoting anxiolysis, preserving spontaneous breathing and airway patency, keeping the patient responsive to verbal or tactile stimulation and hemodynamically stable. A certain degree of amnesia with a low incidence of recall of the procedure is desirable. The goal is to provide conscious sedation (or moderate sedation) during awake tracheal intubation. Sedation cannot be used as a substitute for ineffective topical anesthesia.[26]

Best candidates for awake tracheal intubation

Awake tracheal intubation should be considered whenever a difficult airway is anticipated.[4] When appropriate, awake intubation should be performed whenever difficult tracheal intubation is suspected and one or more of the following factors are present: difficult ventilation (under face mask or supraglottic device); increased risk of pulmonary aspiration; patient cannot tolerate a brief episode of apnea; difficulty in airway rescue with an invasive emergency approach.

Some examples of patients who may benefit from awake tracheal intubation are: personal history of radiotherapy, head and neck surgery or malignancy, glottic tumors, unstable cervical spine, limited mouth opening or cervical extension, previous anesthesia presenting difficult airway, critical patients (physiological difficult airway), and morbid obesity.[27] Preservation of breathing function is highly recommended for such patient groups, as well as pre-oxygenation in a head-up position, optimizing functional residual capacity, and prolonging safe apnea time.[22]

Methods and devices for topical anesthesia

The success of awake tracheal intubation depends on the effective topical application of local anesthetic to the airways, allowing awake tracheal intubation to be performed with minimal or even no sedation, which is an important step in this approach to difficult airway. The Difficult Airway Society's practical guidelines[4] for awake tracheal intubation in adults recommend using a cognitive aid, such as a checklist before and during its execution, emphasizing that the main components of awake tracheal intubation are sedation (optional); topical application of local anesthetic; oxygenation; performance of the physician and team. The maximum dose of lidocaine of 9 $mg.kg^{-1}$ of lean body weight must be respected, regardless of the administration technique.[4] Compared to other local anesthetics, lidocaine has advantages due to its lower cardiovascular and systemic toxicity. The lidocaine plasma peak depends on the total dose, rate and site of injection, administration technique and individual patient factors influencing lidocaine distribution, metabolism, and excretion.[28]

Proper topical anesthesia of the larynx and trachea before tracheal intubation prevents increases in heart rate and arterial blood pressure and reduces the likelihood of coughing during anesthesia wake-up. Several techniques are available: atomizers to disperse the local anesthetic, spray-as-you-go technique (local anesthetic instillation through the flexible intubating bronchoscope working channel or a catheter), and nerve blocks. There is no evidence suggesting the superiority of any technique. However, glossopharyngeal and superior laryngeal nerve blocks are associated with high plasma concentrations of local anesthetic, higher systemic toxicity and reduced patient comfort.[27]

Some authors recommend using topical anesthesia in the initial airway management, and if required using glossopharyngeal and superior laryngeal nerve blocks and transtracheal injections as a complement. Atomizers allow drugs to be dispersed in a fine mist of particles measuring between 30 and 100 micrometers consistently and directly onto the nasal mucosa, pharynx, larynx, and trachea, allowing for excellent local anesthesia. Lidocaine can be nebulized, but as its absorption varies, it may require higher doses, increasing the risk of pulmonary absorption and systemic toxicity.[28]

Notwithstanding the administration route used, the anesthesiologist should maintain a high degree of vigilance for the classic symptoms of local anesthetic systemic toxicity. The symptoms generally start with central nervous system (CNS) excitement, such as circumoral numbness, hearing changes, metallic taste, and agitation. Symptoms can progress to seizures, CNS depression, coma, and cardiorespiratory arrest. Classically, CNS toxicity precedes cardiac toxicity.[27] Lidocaine is the local anesthetic most commonly implicated in systemic toxicity and has been used more frequently in tissue infiltration by surgeons and in intravenous infusions for perioperative analgesia. Between 2017 and 2020, 36 published reports of local anesthetic systemic toxicity were identified, one of which occurred in a healthy volunteer during an awake tracheal intubation training course.[29] Large-volume infiltration or topical application of local anesthetic in highly vascularized tissues present risk, especially for cardiac patients; extremes of age with frailty and muscle wasting; poor blood perfusion conditions; compromised liver function and reduced plasma levels of α1- acid glycoprotein. Immediate management begins with discontinuing local anesthetic administration and calling for help. Regarding neurological symptoms, benzodiazepines can attenuate or suppress seizures. Life support measures should be initiated immediately, including immediate airway control, cardiopulmonary resuscitation protocol according to current guidelines, and infusion of 20% lipid emulsion.[29]

Drugs recommended for sedation during awake tracheal intubation

There are several drugs available, and the choice will depend on factors such as availability and familiarity of the anesthesiologist performing the procedure.[27] Safe doses of benzodiazepines, opioids, α-2 agonists, and hypnotics can be administered alone or combined to avoid ventilatory depression and deep sedation.[27] Among benzodiazepines, midazolam is the most used, usually combined with an opioid. The advantage of the benzodiazepine and opioid combination is the straightforward technique, low cost, availability of reversal agents and the vast experience of anesthesiologists with the combination. The disadvantage, however, is that intermittent boluses can be associated with rapid progression to deep sedation.[4] Hypnotics such as propofol have been investigated in several studies, albeit more focused on target-controlled infusion.

Dexmedetomidine and remifentanil are associated with high patient satisfaction, and low risk of deep sedation and airway obstruction. Dexmedetomidine is a superior agent for use in awake tracheal intubation when compared to midazolam, fentanyl, propofol or sufentanil, as it presents the advantage of providing satisfactory conscious sedation without ventilatory depression, an antisialagogue effect, and moderate analgesia.[30] Cabrini et al.,[26] in the first systematic review of randomized clinical trials focused on fiberoptic intubation in awake surgical patients with a difficult airway, suggested that the different methods for performing awake tracheal intubation are equally safe and effective, but were unable to identify a clearly superior protocol. A high degree of efficacy and safety was observed with minimal differences among protocols and a lower incidence of desaturation or apnea episodes when dexmedetomidine or sevoflurane was used for sedation. Thus, dexmedetomidine may offer a superior safety profile compared to other sedatives.[31]

Contraindications for awake tracheal intubation

In general, there are no absolute contraindications other than patient refusal. Relative contraindications are airway bleeding, allergy to local anesthetics, uncooperative patients (change in level of consciousness), pediatric patients, or situations such as fixed obstruction of the larynx, subglottic stenosis or patient scheduled for elective tracheostomy.[1,4]

Video laryngoscopy

Appropriateness of the video laryngoscope as the first option for tracheal intubation

Tracheal intubation involves three distinct components:

1. visualization of laryngeal structures and the glottic cleft;
2. passage of the tracheal tube through the vocal folds;
3. advancing the tube to the tracheal lumen. Improvement in the visualization of glottic structures is evident with video laryngoscopy (components 1 and 2). Video laryngoscopy also lowers the Cormack-Lehane classification grade when compared to difficult direct laryngoscopy and decreases esophageal intubation rates.[32]

Video laryngoscopy has clear advantages over direct laryngoscopy for tracheal intubation, especially when the first attempt is unsuccessful, or when the airway is known to be challenging. Video laryngoscopy is the first rescue option after failed tracheal intubation by direct laryngoscopy and can be elected as the first technique of choice for managing an anticipated difficult airway. For obese patients, using the video laryngoscope instead of the Macintosh-type laryngoscope is associated with more likely successful tracheal intubation on the first attempt, a result more consistent with the use of a tracheal tube introducer guide.[32] To prevent esophageal intubation, the routine use of a video laryngoscope has been recommended whenever possible, as well as monitoring exhaled CO2 (EtCO2) by capnography and pulse oximetry during any airway control situation.[33]

Video laryngoscopy is a crucial tool for teaching and training the laryngoscopy and tracheal intubation techniques.[34] The quality of imaging provided by the device's screen, with adequate brightness and high definition, facilitates the identification of key landmarks, such as the epiglottis or vocal cords, and enables trainees to guide the tracheal tube more quickly and assertively. Another advantage of training with video laryngoscopy is that the instructor follows the maneuver simultaneously by viewing the screen and can make observations or instant corrections to guide the inexperienced laryngoscopist.[34] Nonetheless, there are disadvantages and limitations. The cost of most devices is still high, curbing their wide availability and use. The equipment may present technical issues or failures such as: lens fogging due to temperature gradient, secretions or blood blocking the camera view, and lack of power due to discharged batteries. Adverse outcomes associated with video laryngoscopy include sore throat, laryngospasm, and lip, dental or mucosal lesions.[32]

Video laryngoscopy is not recommended if one of the following factors is present: mouth opening < 2.5 cm; cervical spine fixed in flexion; patient presenting stridor with airway or upper digestive tract tumor.[1] We recommend evaluating if the video laryngoscope can be introduced into the mouth before anesthetic induction. Desaturation at levels below 95% requires interruption of intubation maneuvers in favor of those that allow oxygenation. If there is a proven risk of hypoxemia, video laryngoscopy cannot replace mask ventilation or using a supraglottic device to properly oxygenate the patient.[1,21]

Airway management after anesthetic induction

How to proceed in an unanticipated difficult airway scenario

Unanticipated difficult airway happens even to experienced clinicians. Strategies should preferably be planned before anesthetic induction. Failure in the initial approach may occur and subsequent plans must be well established. The first step is to avoid fixation error (a cognitive error that occurs when the clinician focuses on just one aspect of care and overlooks others more relevant). The number of attempts per device should be limited. We recommend that the maximum number of attempts with the same device should be three, and that, upon a new attempt, the oxygen supply to the patient should be optmized.[21]

Whenever a tracheal intubation attempt fails, one should call for help early and disclose to the team involved that the initial plan could not be executed, in order to improve team awareness of the condition. Be aware of elapsing time, the number of attempts and oxygen saturation.[20] We recommend checking the ventilation with a face mask by connecting a capnograph to the mask and by monitoring arterial oxygen saturation (SpO2) throughout the process.

Confirmation of adequate ventilation by capnography and maintenance of SpO2 in a safe range enables the clinician to consider which device is most suitable for a given patient. There are several alternatives: video laryngoscopes, alternative laryngoscope blades (change of size or shape), flexible intubating bronchoscopes, bougie-type introducer guides, optical stylets, external laryngeal maneuvers, or a combination of techniques (combining video laryngoscopy and a bougie introducer, for example).[1]

Alternative techniques must be chosen according to the knowledge and skills of the clinician handling the case. It is important to avoid multiple attempts with the same device, as they can cause airway trauma, leading to worse face mask ventilation, deterioration of SpO2, and progression to a cannot intubate, cannot ventilate scenario.[20]

It is worth underscoring that there are situations in which a decision must be made to continue the procedure using an alternative device (e.g., maintain ventilation with face mask or supraglottic device) when it is impossible to perform tracheal intubation without harming the patient, provided that the ability to keep an adequate ventilation is preserved. Waking the patient, postponing the case, or delaying intubation and rescheduling the case with more suitable resources should be considered.[1]

What should be done during the "cannot intubate, cannot ventilate" scenario

After anesthetic induction, the inability to intubate and ventilate the patient at the same time may occur. This is rare, but extremely challenging and depends on logical, sequential, and quick thinking to prevent catastrophic complications. We initially recommend that the first laryngoscopy attempt be performed with the dominant eye, with optimized positioning of the patient and operating table, and using the bimanual technique. Equally, face mask ventilation should be optimized using oropharyngeal cannulas (e.g., Guedel cannula) and the four-handed ventilation technique. If ventilation and/or tracheal intubation fails, help must be requested immediately.[1,20]

At this time, immediate ventilation rescue must be obtained using, preferably, a second-generation supraglottic device with a gastric drainage channel and designed to facilitate intubation through the device's internal lumen.[1] If successful, adequate oxygenation has been achieved once again, allowing for alternatives for continuing the case or deciding on equipment for performing the tracheal intubation, or even canceling or postponing the case.

If the chosen supraglottic device fails, the recommendation is to try another one, preferably with a format different from the one previously attempted, provided that oxygen saturation is kept at acceptable levels and the patient does not present severe bradycardia.[1,20] If adequate oxygenation cannot be sustained and when it is impossible to awaken the patient, an invasive technique will be necessary to manage the airway. Several invasive techniques have been described: surgical tracheostomy, surgical cricothyroidotomy, needle cricothyroidotomy and pressure-regulated ventilation, and large-caliber cannula cricothyroidotomy (including the approaches using the Seldinger technique over a guide wire).[1,20,21]

If the cricothyroid membrane is palpable, the percutaneous technique can be performed. We recommend large-caliber cannulas (with an internal diameter above 4.0 mm), as they can deliver ventilation with low-pressure devices such as bag-valve device or conventional mechanical ventilator. We do not recommend using small-caliber cannulas, as they must be ventilated using high-pressure devices, which are not routinely available in hospitals in countries with limited resources.

Open surgical cricothyroidotomy is the fastest and most reliable method for securing airway control in an emergency scenario.[1] Several surgical techniques have been described, but there is no evidence of superiority of one over another.[1] All techniques have common steps: cervical extension, cricothyroid membrane identification, incision through the skin and cricothyroid membrane, and insertion of the cuffed tracheal tube. The Difficult Airway Society recommends the sequential use of a scalpel, bougie introducer and tracheal tube. This technique must be performed with the patient's head in cervical hyperextension and associated with a neuromuscular blocker. With the cricothyroid membrane palpable, a transverse incision is made in the skin and cricothyroid membrane (sharp edge directed caudally), the bougie introducer is inserted into the trachea towards the patient's chest until resistance to progression is found, usually after approximately 15 cm of the bougie is inserted. Then, using the bougie as a guide, a 6.0 mm cuffed tracheal tube is pushed down the trachea and the bougie is removed. After inflating the tracheal tube cuff and confirming tracheal intubation capnography, the tracheal tube should be properly secured. When the cricothyroid membrane is impalpable, an 8-10 cm vertical midline skin incision is made, caudad to cephalad. Blunt dissection with the fingers of both hands separates tissues to identify and stabilize the larynx in order to incise the cricothyroid membrane, followed by the steps described above.[1,20,21]

When to awaken the patient, cancel or postpone the procedure

Postponing or canceling the case has the following main objectives: wait for or request specialized help, optimize the preparation of the patient, change strategy and perform awake tracheal intubation, or wait for the arrival of suitable equipment unavailable at the time. Therefore, if the case is not an emergency, this strategy should be contemplated before proceeding with alternative airway approaches.[1]

Human factors in airway management

Human factors and how they are related to the management of difficult airway

Human factors constitute the scientific discipline that examines interactions between humans and system components. It aims to improve clinical performance by acknowledging the impact that teamwork, tasks, equipment, workspace, culture, and organization have on human behavior and applying this understanding to clinical situations.[35] By their very nature, humans inevitably make mistakes. The study of human factors tries, first, to estimate the likelihood of an error occurring, and then to establish barriers to prevent the error to progress and harm the patient.[36] Up to 80% of anesthetic adverse events are human error-related.[37] In the UK, the study linked to the 4th National Audit Project (NAP4) concluded that issues related to human factors (poor judgment, ineffective communication and poor teamwork) were present in 40% of major complications in airway management and were considered as factors impacting the outcome in 25% of cases.[38] The most critical points were failure to anticipate risks, incorrect decisions, difficulty in performing tasks, untrained practitioners, time pressure, tiredness, hunger, stress, poor communication and limitations in competence. Overall, the contribution of human factors, related to issues harming the patient during airway management, is at least as important as those arising from technical problems.[39]

Non-technical or soft skills

Currently, the complexity of patient care requires anesthesiologists with a wide range of skills and attributes. Traditional training has placed great emphasis on acquiring technical knowledge and practical skills to ensure competent services. However, some social behaviors, psychological states and cognitive functions relate to superior outcomes and lower rates of adverse events. These attributes have been called non-technical skills or soft skills and have been identified as teamwork, task management, decision making, and situational awareness. They can also be classified as cognitive and mental skills (planning, decision-making under pressure, dealing with stress, situational awareness, appropriate use of technology) and social and interpersonal skills (teamwork coordination, leadership, effective communication).[40,41]

Efficient teamwork depends on the exchange of relevant information in a coordinated and fast way to execute tasks. Skills and abilities of team members must be identified, and roles assigned, seeking to explore the best in each individual, but paying attention to avoid stress and fatigue. The different tasks must be executed in a coordinated and simultaneous manner, with all team members supporting and assisting each other. The responsibility lies with all members and not individuals.

Decision-making is based on the prior identification of possible options in a given scenario. Discussion with the team and the support of algorithms help reach the correct choice. It is necessary to continually reassess the scenario and, if required, change or adjust decisions. Task management is also known as leadership. A good leader plans and gets ready to execute tasks and must be aware of the available resources and their appropriate use to achieve goals. A leader must always be aware of priorities and be focused on patient safety and quality of care. Situational awareness is the perception of environmental elements and events concerning time or space, the understanding of their meaning, and the prediction of their future status. Situation awareness is a critical foundation for successful decision-making in a wide range of situations in medicine, aviation, industry, and education. Lack of situational awareness has been identified as a major factor in accidents attributed to human error. Self-knowledge to recognize one's abilities and limitations in a given situation is essential. Collecting and analyzing information on the patient's condition and comparing it to expected standards or goals in a systematic way enables the establishment of diagnoses and the planning of the next steps.[42]

Stress is one of the most important factors impacting human behavior. It undermines cognitive status, effective communication, and both technical and non-technical skills, which damage the ability to respond to a crisis. Although stress susceptibility may differ among individuals in terms of impact on performance, it is present in everyone, if pressure exceeds limits. Stress-related cognitive impairment can cause fixation error, distorted perception of time, memory failure, and impaired judgment. These issues can induce even experienced physicians to make mistakes in matters that are considered basic when managing airways in emergency situations. A common event during airway management is the fixation on tracheal intubation, overlooking alternatives for oxygenating the patient using a face mask or a supraglottic device.[43]

How to develop and apply non-technical skills

Training and continuing education are fundamental for attaining practitioners with high technical capacity and non-technical skills. Some teaching tools can be used, such as the mnemonic ARACHNID,[36] which includes the following parameters: Algorithms — use algorithms to direct management; Resilience — when an event occurs, listen and support those involved, and solve it to prevent the event from recurring; Cognitive Aids — cards or warnings with structured and quickly available information to improve clinician cognition and adherence; Checklists; Handover — it is vital to comprehensively transfer patient information and continuity of care; Non-technical skills — they are crucial tools, such as communication, teamwork, situational awareness, avoiding task fixation, leadership and continuity, hierarchy and stress management; Incident investigation; Design of equipment, packaging, drugs, operating rooms, modern and intelligent emergency rooms — create barriers to mistakes and facilitate best practices.

Another fundamental tool is realistic simulation, which has been increasingly used as a training and knowledge retention strategy. By following the concepts of crisis resource control, realistic simulation enables teaching and assessing skills required to effectively overcome crises. Moreover, high-fidelity simulation tools enable reenacting complex clinical situations to analyze individual or team behavior during decision-making processes. Simulation also allows reviewing concepts based on scientific literature to discuss and provide feedback on behavioral aspects of performance, and evaluate and understand the difficulties found.[31]

Initiatives such as The Airway Lead or Rapid Response Teams projects to control the airway proved their extreme importance during the COVID-19 pandemic. Non-technical aspects were highlighted while training the teams responsible for managing the most critical cases, often under great pressure and psychological stress.[44,45]

Confirmation of intubation

Methods available to confirm tracheal intubation

According to the CFM Resolution #2,174/2017,[5] the minimum safety conditions for the practice of anesthesia comprise the availability of continuous monitoring of oxygen saturation of hemoglobin through pulse oximetry and continuous monitoring of ventilation through exhaled carbon dioxide levels by capnography, in the following situations: anesthesia using an airway device (such as tracheal or bronchial intubation or supraglottic device), clinical situations requiring artificial ventilation, or exposure to triggering malignant hyperthermia agents. Thus, all tracheal intubations must be confirmed and monitored using continuous waveform capnography, considered the gold standard for confirming intubation given its sensitivity of 98 to 100% (percentage of tracheal intubations correctly detected by a positive test result) and 100% specificity (percentage of esophageal intubations correctly detected by a negative test result).[46] Capnography generally provides earlier confirmation of effective ventilation than SpO2, which should also be employed continuously during airway management. Continuous monitoring capnography waveform must be used in all intubated patients, in every hospital area, including during patient transportation inside the hospital.[46]

After tracheal intubation, if proper tube positioning is uncertain, the clinician must decide between removing the tracheal tube or optimizing ventilation. Additional techniques to confirm tube positioning can also be used, namely: visualization techniques (any technique), flexible bronchoscopy, ultrasound or radiological examinations.[1] Systematic reviews and meta-analyses have revealed that ultrasound is a valuable and reliable accessory tool for determining correct tracheal tube location, including resuscitation in cardiorespiratory arrest.[47,48] According to Chrimes et al.,[33] the standard reaction when an expected $ETCO_2$ waveform is not shown should be to remove the tracheal tube and attempt ventilation using a face mask or supraglottic device. Clinical examination should not be used to rule out esophageal intubation. The tracheal tube should be removed if any of the following conditions are true: esophageal intubation cannot be ruled out; $ETCO_2$ waveforms are absent; SpO_2 deteriorates before the $ETCO_2$ sustained curve resumes.

Safe tracheal extubation

When to extubate the patient

Careful tracheal extubation planning increases safety and prevents complications. Although the rate of extubation failure or reintubation in the operating room after a surgical procedure is relatively low (0.1% to 0.45% incidence), when it occurs, the event is related to increased mortality.[49] Extubation failure after general anesthesia is defined by the patient's inability to maintain a patent airway and spontaneous ventilation, after intentional tracheal extubation, within a specified time. The NAP4 report revealed a mortality rate of approximately 5% associated with extubation failure after general anesthesia and an incidence of severe complications in 13% of patients presenting extubation failure.[38] One in every six severe adverse events related to airway management occurred at the end of anesthesia or upon arrival at the post-anesthesia care unit.[38]

After the end of any anesthetic procedure, the anesthesiologist must evaluate whether the patient is fit for extubation. Every extubation must be elective, and it is necessary to select the appropriate moment and place to execute it, for example, in the operating room, post-anesthesia care unit or intensive care unit. Postoperative residual neuromuscular blockade remains a frequent issue, with a reported rate between 20% and 64%.[50] In most elective cases, extubation can be done in the operating room, as long as physiological parameters are stable, recovery from anesthetic effects is complete and reversal of neuromuscular blockade is adequate. At the time of extubation, it is crucial to ensure the immediate availability of supplemental oxygen, reintubation equipment and the presence of an assistant.[21] Monitoring ventilation, airway patency and maintaining continuous oxygenation until complete recovery are essential after tracheal extubation.[21]

How to design a strategy for extubation and subsequent airway management

Algorithms can reduce complication rates related to extubation and the need for reintubation. The detection of the risk factors related to the patient's physical status and comorbidities and the possible clinical repercussions caused by anesthesia and surgery is essential. Thus, several guidelines and cognitive aids have been made available: 1. Proper extubation requires meticulous preparation, comprising reversal of residual neuromuscular blockade, preoxygenation, appropriate positioning, effective team communication, and planning the management of potential complications after extubation. The strategy will depend on the type of surgical procedure and the patient's clinical status at the end of the intervention, but also on the skills and preferences of the attending physician; 2. Assuring that a qualified assistant is present for support for treating potential complications related to extubation; 3. Assessing the indication and feasibility of short-term use of an airway exchange catheter and/or supraglottic devices that can be used as alternatives for oxygenation and fast-track reintubation; 4. Before attempting extubation, assessment of the risks and benefits of elective surgical tracheostomy in specific situations; 5. Assessment of the risks and benefits of awake extubation versus extubation before return to consciousness. Patients who require suppression of hemodynamic responses may benefit from awake extubation associated with drugs attenuating the hemodynamic response, or extubation under deep anesthesia using a supraglottic device, aiming at a smoother transition during awakening; 6. Use of supplemental oxygen throughout the extubation process.[21,49,51]

Most complications related to extubation can be prevented. Before extubation, the clinician must carefully prepare all necessary resources to deal with fairly predictable complications. Practical guidelines are useful in rare and serious situations, and some evidence has suggested superior results when using them.[1,51]

Clinical factors that increase the risk of extubation failure

Obesity, asthma and chronic obstructive pulmonary disease are the most common comorbidities associated with adverse events related to airway management. According to data from the NAP4 report, upper airway obstructions caused by laryngospasm, tracheal tube or supraglottic devices are among the main causes of airway complications during awakening and post-anesthesia recovery.[38] Upper airway obstruction, even when short-lasting, can cause post-obstructive pulmonary edema (or negative pressure pulmonary edema) and severe hypoxia. In most reported events, the time window from upper airway obstruction onset to pulmonary edema symptoms was only a few minutes.[52]

Other frequent causes of airway obstruction are edema and bleeding, especially after head and neck surgeries and Ear-Nose-Throat procedures. Airway bleeding requires careful inspection and thorough suctioning before tracheal extubation. Cervical hematoma can cause airway edema and obstruction due to reduced venous drainage and can render reintubation significantly difficult, even in patients showing easy direct laryngoscopy at the beginning of the procedure. Surgical manipulation can produce glottic and periglottic edema, disrupt airway patency and cause obstruction. Other conditions may also be associated with this mechanism, such as multiple tracheal intubation attempts in difficult airway situations, fluid overload, pre-eclampsia or angioedema.[51]

Robotic surgery has increased the use of the Trendelenburg or steep head-down position, which can cause atelectasis and significant reduction in lung compliance, worsen intraoperative ventilation mechanics, and can contribute to desaturation after tracheal extubation. Airway edema can take place in between 0.7 and 26% of patients.[53] Clinicians should pay special attention to a triad of airway risk factors: head-down position, high peak pressure during mechanical ventilation and fluid overload.[53] In the presence of the triad, it is vital to exclude significant edema, subcutaneous emphysema, barotrauma, and pneumothorax before tracheal extubation.

The main risk factors for postoperative reintubation are residual neuromuscular blockade, preventable human factors (inexperience, lack of standardized procedures), clinical conditions reducing cardiac or pulmonary functional reserve and airway obstruction.[21]

How to manage morbidly obese patients and obstructive sleep apnea-hypopnea syndrome after tracheal extubation

Morbidly obese patients, with or without obstructive sleep apnea-hypopnea syndrome (OSAHS), should prophylactically receive supplemental oxygen in the upright or semi-sitting position.[54] Both groups can be safely monitored in a surgical ward after discharge from the postanesthetic care unit. NIPPV devices, such as CPAP (Continuous Positive Airway Pressure) or BiPAP (Bilevel Positive Airway Pressure), should be considered in the presence of ventilatory discomfort. Patients with OSAHS using CPAP or BiPAP at home preoperatively must use the device during the immediate postoperative period. Patients with obesity hypoventilation syndrome (obese patients presenting chronic daytime hypercapnia) have an increased risk of developing perioperative ventilatory adverse events. NIPPV should also be considered in the immediate postoperative period in this patient population, mainly in the presence of hypoxemia.[54]

Conflicts of interest

The authors declare no conflicts of interest.

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