Chapter 14
Advanced and Difficult Airway Management in the ICU

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Introduction

Endotracheal intubation in critically ill patients can be difficult and associated with significant morbidity and mortality [1–3]. Patients have underlying life-threatening pathology, may be hypoxemic and hypotensive, and may not tolerate induction and neuromuscular blockers well. Intubations in the ICU may differ vastly from intubations in the operating room which are often elective and performed in a controlled setting by trained anesthesiologists. Incidence of difficult intubation in the ICU as reported in literature ranges from 1% to 23% depending on the definition of the difficult intubation and center [4–7].

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The field of airway management has undergone a revolution in the last several decades with the development of vast array of airway devices and algorithms. Supraglottic airways (i.e., laryngeal mask airways) have firmly established their role as a rescue device, and widespread use of indirect laryngoscopy in the form of video laryngoscopes has improved first-time success of endotracheal intubation. In this chapter, we will discuss some of the more advanced airway management techniques that an intensivist may need to utilize in the ICU.

Case Presentation

The patient is a 65-year-old man with a medical history significant for thoracoabdominal aneurysm, coronary artery disease (history of left anterior descending artery stent placed 2 years previously for angina, normal ejection fraction, asymptomatic), chronic obstructive pulmonary disease (no home oxygen, on ipratropium/albuterol combination inhaler, current smoker with a 40-pack year smoking history), and obesity (height 70 inches, weight 125 kg, BMI 39.5 kg/m^2). The thoracoabdominal aneurysm was found incidentally on computed tomography scan of the abdomen obtained 2 years previously on work-up for upper abdominal pain. He was followed with serial ultrasounds and presented for elective repair when the maximum diameter of the aneurysm exceeded 5 cm. Lung isolation was achieved using a 41 French double-lumen endotracheal tube. Intubation was moderately difficult requiring two attempts by an experienced anesthesiologist with only arytenoid cartilage visible during direct laryngoscopy. The total procedure length was 8 hours with an aortic cross clamp time of 90 minutes. Intraoperatively, he received 12 liters of isotonic crystalloid fluid, 8 units of packed red blood cells, 3 units of fresh frozen plasma, and a dose of platelets. The estimated blood loss was 2 liters and the urine output was 3 liters. At the conclusion of the procedure, the patient was left intubated due to the need for ongoing mechanical ventilation in the setting of a prolonged, high blood-loss surgical procedure which required a large-volume administration of crystalloid and blood products intraoperatively. It was also recognized that the patient would likely have an ongoing inflammatory response due to the long aortic cross clamp time. The double-lumen tube was left in place due to concerns for the safety of the patient when replacing the double-lumen tube with a conventional single-lumen endotracheal tube. At that point, the patient had marked facial edema and probable airway edema. As noted previously, the patient was moderately difficult to intubate by an experienced laryngoscopist when he had no edema. The patient was admitted to the ICU, and over the following 16 hours, he required an additional 10 liters of isotonic crystalloid fluid due to a significant systemic inflammatory response. The following morning, he remained obtunded with significant ventilator requirements (fraction of inspired oxygen 60%, PEEP 10 cm H_2O). He had thick secretions that were being inadequately suctioned due to small lumens of the double-lumen tube. On exam, he had severe anasarca with marked edema of the face, lips, tongue, chest/abdominal walls, and extremities. The impression was that he would require mechanical ventilation for a minimum of 7–10 days.

He requires replacement of the double-lumen tube with a conventional single-lumen endotracheal tube due to pulmonary toilet requirements and the need for prolonged mechanical ventilation. What are the options for managing the airway of this patient?

Recognizing the Difficult Airway

It is important to recognize the potential for a difficult airway in order to best prepare for airway management. This should always begin with careful evaluation and planning. Identification of difficult airway management remains challenging, but several patient factors that would suggest potential airway management difficulty include:

Table 14.1 Mallampati classification for mouth opening

Mallampati classification	Visualization
Class I	Soft palate, fauces, uvula, tonsillar pillars
Class II	Soft palate, fauces, uvula
Class III	Soft palate, uvular base
Class IV	Hard palate only

1. Mallampati Classification of III or IV. Patients with Mallampati Scores of III and IV Are Predictably more Difficult to Intubate than Patients with Mallampati Scores of I or II (Table 14.1).
2. Short thyro-mental distance. A thyro-mental distance less than 3 fingerbreadths (approximately 3 cm) suggests an anteriorly placed larynx that may be difficult to visualize using direct laryngoscopy.
3. Limited mouth opening. Inter-incisor distance of less than 3 fingerbreadths (3 cm) with the mouth fully open.
4. Limited head and neck movement. Neck extension could be limited by disease (arthritis, ankylosing spondylitis, prior fusion) or trauma (neck immobilized to protect against spinal cord trauma).
5. Obesity.
6. Large volume of airway secretions.
7. Blood in the airway.
8. History of difficult intubation. This is the most specific indicator of a difficult airway. Unexpected difficult intubations are often the most difficult to manage since preparations for a difficult intubation have not been made. It is important to question the patient and/or family and scan the medical record to determine if the patient has had a difficult intubation in the past. Similarly, it is important that providers who have encountered difficult intubations adequately document the event and inform the patient and family.

9. Syndromes with associated airway abnormalities (i.e., Pierre Robin, Treacher Collins, Downs, Goldenhar, etc.).
10. Tumors/lesions involving upper airway structures including the tongue, oral cavity, tonsils, larynx, etc.
11. Tumors/lesions involving the trachea.
12. Marked edema of the face, tongue, and/or airway.

Independent Risk Factors for Difficult Mask Ventilation

The ability to predict difficulty of bag-mask ventilation is as important as identifying factors for difficult intubation [8]:

1. Presence of beard
2. BMI > 26 kg/m^2
3. Lack of teeth
4. Age > 55 years
5. History of snoring

Airway Management

The goal of respiratory support is to enable the patient to adequately oxygenate and ventilate. Patients with mild to moderate pulmonary insufficiency may need only supplemental oxygen and an ability to clear secretions on their own to achieve this goal. Patients with respiratory failure either due to general anesthesia or disease often require positive pressure ventilation and supplemental oxygen (mechanical ventilation) to achieve these goals. Most often, an endotracheal tube is placed in order to protect the airway from aspiration while providing optimal mechanical ventilation. Endotracheal tubes enter the patient via the mouth (oral endotracheal tube) or nares (nasal endotracheal tube) or directly into the trachea through the neck (tracheostomy appliance). For the purpose of this chapter, we will refer to the process of securing the airway with an endotracheal tube as airway management.

When placing patients under general anesthesia for surgical procedures, airway management is determined by surgical factors and patient factors. Surgical factors are numerous and include procedure duration, procedure site, positioning, and laparoscopic versus open procedures. Patient factors include the predictors of difficult airway discussed previously as well as comorbid conditions including gastroesophageal reflux disease, esophageal achalasia, and baseline pulmonary disease. For elective operations, patients are usually breathing comfortably and can be preoxygenated. Preoxygenation removes the 79% nitrogen from the functional residual capacity of the lungs which maximizes the amount of time available for intubation. In addition, the option usually exists to cancel the procedure before induction of anesthesia if airway management is deemed too risky or to abort the procedure if attempts to secure the airway after induction are unsuccessful. Consideration can be made for using an alternative means of securing the airway, such as an awake intubation technique with flexible fiber-optic bronchoscopy. There are society guidelines, such as the American Society of Anesthesiologists difficult airway guidelines [9], which help with this decision-making (Fig. 14.1).

In the ICU, the option to abort attempts to secure the airway or to perform an awake intubation is usually not available due to respiratory distress or ventilator dependence. The goal in airway management should always be to not make the respiratory status of the patient worse. While this concept seems to be self-evident, there are often many good arguments to make adequate airway access better. At that point the risks and benefits of changing the airway must be carefully considered.

In the example noted in the case presentation, even a large double-lumen tube (41 French) is difficult to manage long-term. Exact dimensions vary by manufacturer, but each lumen of the 41 French double-lumen tube is small with an inner diameter of 4.6 to 5.4 mm. It has a maximal outer diam-

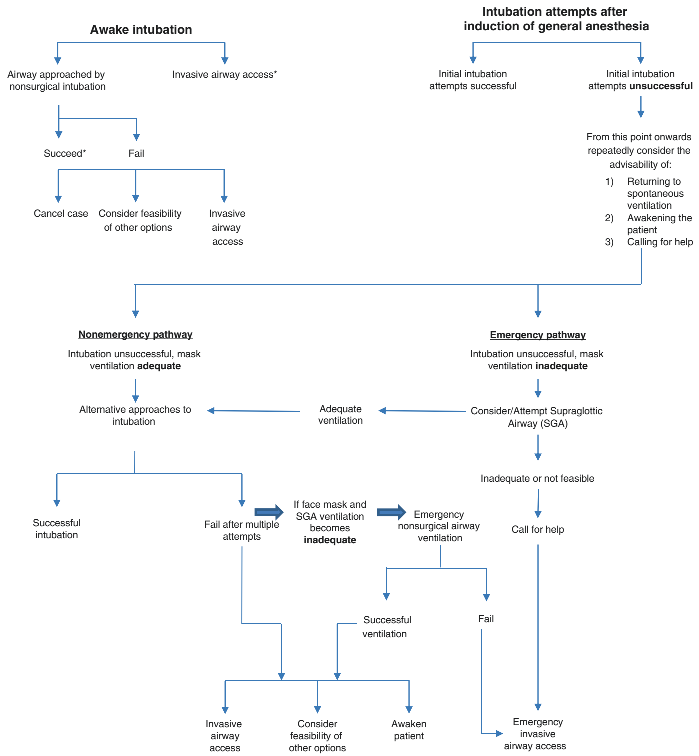

Figure 14.1 Modified from Apfelbaum et al. [9]. Please refer to *Apfelbaum* et al. for more details

eter of 14.3–14.9 mm. A 39 French double-lumen tube has a maximal outer diameter of 14.2–14.4 mm. Compare these dimensions with those of an 8.0 single-lumen endotracheal tube which has an inner diameter of 8.0 mm and an outer diameter of 11 mm. Therefore, it is more difficult to suction secretions from a patient with an appropriately sized double-lumen tube due (39 or 41 French) compared to a patient with a convention, 8.0 single-lumen endotracheal tube. In addition, compared to a single-lumen tube, the larger diameter of the double-lumen tube increases the probability of glottis injury especially when endotracheal intubation is required for a prolonged period of time. Suboptimal pulmonary toilet and increased risk for glottis injury are both good arguments to switch from a 39 French or 41 French double-lumen tube to an 8.0 single-lumen tube. However, exchanging an endotracheal tube in this situation can be challenging and quite risky.

The safest way to manage this airway would have been placing a conventional single-lumen tube preoperatively and isolating the lung using a bronchial blocker. No endotracheal tube exchange would have been required. Unfortunately, lung isolation may be less than ideal for surgical exposure. Also, bronchial blocker placement can sometimes be challenging. Both could preclude using a conventional, single-lumen endotracheal tube for the procedure. Another option would be exchanging the tube in the operating room prior to transfer to the ICU. In this case, the tube would be exchanged in the relatively controlled environment of the operating room by an anesthesiologist with extensive airway expertise with ready availability of a surgeon for a surgical airway. Also, predictably, there would likely be less facial and airway edema immediately postoperatively than 12–24 hours later after an additional large volume of IV fluid. This stresses the importance of communication between the anesthesiology team and ICU team which would have ideally started before the surgical procedure.

As alluded to earlier, airway management outside of the operating room or procedure site tends to be more difficult due to a variety of reasons. Most times, airway management is not elective. The patients usually have not been fasting. In the critical care setting, they tend to have an ileus. They are therefore at increased risk for aspiration. Furthermore, respiratory distress and underlying disease reduce the number of options. The factors noted previously that are associated with difficult intubations are more prevalent in the ICU population than in the general population. Staff of the ICU should be prepared for the urgent need for airway management at all times. This includes having supplemental oxygen, suction, equipment for bag-mask ventilation, laryngoscopes, endotracheal tube sizes in a variety of sizes, endotracheal tube stylets, induction medications, a carbon-dioxide detection device, appropriate monitors, and backup equipment all readily available. Backup equipment could include cricothyroidotomy kits, laryngeal mask airways, video laryngoscopes, airway exchange catheters, and tracheal bougies.

In addition to always being prepared for urgent/emergent airway management, anticipating the need for airway management in the near future is critical. Ideally, airway management is done during normal waking hours when staff members with airway management experience are readily available. Furthermore, if an airway is anticipated to be particularly challenging, surgical backup should be arranged for in advance. If the need for special equipment is expected, that equipment could be obtained in advance.

The general approach to airway management is as follows:

1. The patient is preoxygenated and is monitored with the standard monitors at minimum. This includes ECG, noninvasive blood pressure measurements, and pulse oximetry. Mask assist ventilation is provided if necessary.
2. The patient is induced. Induction agents are determined by the patient's clinical status and are beyond the scope of this chapter. Chemical paralysis will most likely facilitate intubation but should be used with caution. Succinylcholine can lead to hyperkalemic cardiac arrest and is associated with malignant hyperthermia. The risk for hyperkalemia is higher in the ICU population than in the general population. In addition, the risk of being unable to ventilate the patient after paralysis must be considered. The non-depolarizing neuromuscular blocking agents in the past were not immediately reversible. Recently, the FDA has approved sugammadex, a novel drug which binds rocuronium and vecuronium and can rapidly reverse neuromuscular blockade. Sugammadex may not be readily available at all centers.
3. Once induced, there should be multiple options for airway visualization and endotracheal tube placement. For most cases, direct laryngoscopy can be used. If unsuccessful, consideration for a second attempt can be made. Our practice

is to limit attempts by any one individual on the team for any particular method to two. Thereafter, either a different individual should attempt airway placement or a different technique should be used. The intent is to minimize failed intubation attempts and the associated morbidity. Morbidities include injuries associated with hypoxia, injuries to the airway, and worsening airway edema. The different options will be discussed.

4. After placing the airway device, successful placement should be confirmed by checking for end-tidal carbon dioxide. Proper positioning is assessed by auscultation and chest X-ray.

There are a number of devices available to provide adequate oxygenation and ventilation. A secure airway is considered to be a tube positioned in the trachea. Most commonly oral endotracheal tubes or tracheostomy appliances are used to secure the airway. Endotracheal tubes are placed using the following methods:

1. *Direct laryngoscopy*: This is the most commonly used method for endotracheal tube placement. Laryngoscopes are relatively inexpensive but require a significant amount of experience for facile use. Patient positioning is important.
2. *Video laryngoscopy*: Video laryngoscopy has revolutionized airway management. These items vary somewhat by manufacturer. There are some video laryngoscopes which use traditional laryngoscope blades such as Macintosh and Miller blades. This allows trainees to perform traditional direct laryngoscopy or video laryngoscopy while the instructor assesses their performance on a monitor. The instructor can provide verbal feedback and/or indirect assistance with external manipulation of the airway. The GlideScope is a video laryngoscope manufactured by Verathon. The GlideScope blade is curved but has more angulated tip than the Macintosh blade. This may allow for better visualization of an anteriorly positioned larynx than would be possible with a Macintosh or Miller blade. In our experience, successful intubation is more likely achieved

using the rigid, curved, endotracheal tube GlideRite stylet. This is due to the ability to better direct the endotracheal tube tip toward the entrance to the larynx. The GlideRite stylet is also manufactured by Verathon. Video laryngoscopy has greatly reduced the incidence of prolonged intubation attempts at our institution.

3. *Flexible bronchoscopy*: Performance of awake fiber-optic bronchoscopy (Fig. 14.2) is probably the gold standard for a difficult intubation. The airway can be made insensate using topical local anesthesia and/or nerve blocks. Only a moderate amount or no IV sedation is needed. The airway can then be secured with the patient awake and spontaneously breathing, thus eliminating the risk of airway loss while securing the airway. Unfortunately, this method is of little or no use in noncooperative patients or in patients with respiratory distress. Asleep, fiber-optic bronchoscopy can be used but can be less than ideal in patients with marginal oxygenation (high A-a gradient) or in patients with a large volume of secretions.
4. *Lighted stylet*: The lighted stylet (light wand) is a flexible stylet with a very bright light source at its tip (Fig. 14.3). This is an indirect intubation technique where the endotracheal tube is positioned while assessing the brightness of the stylet tip under the skin and is performed with the patient under general anesthesia. This has been very helpful in situations where neck movement needs to be

FIGURE 14.2 Karl Storz fiber-optic bronchoscope

FIGURE 14.3 Light wand lighted stylet by vital signs

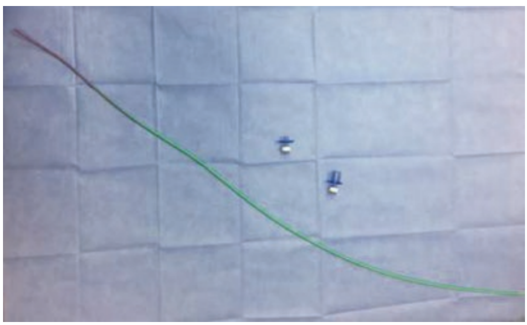

FIGURE 14.4 Cook airway exchange catheter (11 French, 100 cm)

minimized and where movement with coughing could be detrimental. We find this most useful for patients with unstable cervical spine injuries. This technique does require a significant amount of practice. Also a very dark room in required. Ambient light at any level, such as through a shaded window, makes this technique very difficult.

5. *Airway exchange catheter*: Use of an airway exchange catheter (Fig. 14.4) is one of our preferred techniques when replacing an appropriately placed endotracheal tube in a perceived challenging airway. This technique is used if the current tube is damaged, is blocked with secretions, or is inappropriate for the clinical situation. Inappropriate endotracheal tubes include conventional, single-lumen tubes that are too small or double-lumen tubes. Limitations to this technique include an exchange catheter that is too large to pass through the preexisting endotracheal tube or too

small for the replacement endotracheal tube. It is sometimes difficult or impossible to remove an endotracheal tube over an exchange catheter that is too large while keeping the exchange catheter in the trachea. Similarly, if the exchange catheter is too small or not rigid enough, the new endotracheal tube may get snagged on an airway structure, such as a vocal cord, which could leave the patient with no airway. An additional potential complication is airway trauma passing the exchange catheter too deep into the airway. Cook produces a number of airway exchange catheters of varying diameters and lengths. Exchange catheters designed for double-lumen tube replacement have a flexible tip and are relatively rigid. The flexible tip lowers the risk of deep airway trauma. The increased rigidity reduces the risk of displacement of the catheter from the trachea during exchange of the endotracheal tube.

6. *Intubating laryngeal mask airway (LMA)*: Endotracheal tubes can be passed through a conventional LMA or an LMA designed specifically for this purpose. This allows for easier oxygenation and ventilation of the patient between intubation attempts. If the LMA is properly positioned, a relatively small (6–6.5 mm internal diameter) endotracheal tube can then be passed blindly or over a flexible bronchoscope into the trachea through the LMA airway tube. Some LMAs are manufactured specifically for this purpose (Fig. 14.5). Limitations to this technique include the small

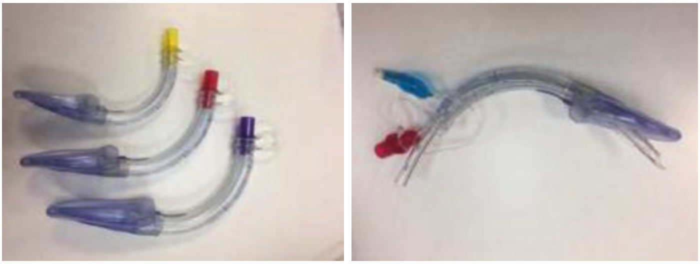

FIGURE 14.5 Disposable air-Q intubating laryngeal mask. Different sizes of the air-Q (left), picture of an endotracheal tube through the inner lumen of the air-Q (right)

Figure 14.6 Cook retrograde intubation set

endotracheal tube size needed to pass through an LMA and the difficulty in properly positioning a laryngeal mask airway in patients with difficult airway anatomy.

7. *Retrograde wire intubation*: This technique requires a percutaneous puncture through the cricothyroid membrane and passing a wire blindly into the hypopharynx, through the pharynx and then out the mouth. An airway exchange catheter is then passed over the wire followed by passing an endotracheal tube into the trachea over the exchange catheter. The most common indications include unstable cervical spine, fracture of the mandible, upper airway mass, and inability to visualize vocal folds due to blood, secretions, or anatomic variations. Commercial kits are available (Fig. 14.6).

The Difficult Airway Response Team

Some institutions, including the authors', have a Difficult Airway Response Team (DART). This multidisciplinary team which includes anesthesiologists, otolaryngologists, trauma surgeons, and emergency medicine physicians is for patients

Figure 14.7 University of Rochester Medical Center carts. Mobile Difficult Airway Response Team cart (left), mobile emergency surgical airway cart (right)

with known difficult airways or those who have failed standard attempts at intubation. This team provides around-the-clock coverage in the hospital and has the ability to obtain an emergent surgical airway if needed. At the University of Rochester, this team was developed under the direction of Dr. Zana Borovcanin. Figure 14.7 illustrates two carts that are emergently brought to any DART activation at our institution.

A Reasonable Approach

A reasonable approach to the case presented at the beginning of the chapter is as follows. Using an 11 Fr, 100 cm long soft-tipped Cook catheter specifically designed for double-lumen endotracheal tubes, the 41 French double-lumen endotracheal tube could be replaced with an 8.0 mm inner diameter conventional endotracheal tube. The patient should be ventilated on 100% oxygen for several minutes prior to the exchange attempt to maximize the time available to make the exchange. The exchange should be planned for during the workday with provisions made for surgical backup. In addition, backup airway equipment including conventional laryngoscope, video laryngoscope, and LMA should be on hand. The patient should be appropriately sedated for the procedure. It would be reasonable to chemically paralyze the patient for the procedure to facilitate the exchange. A successful approach for us is performing the endotracheal tube exchange either under direct vision using direct laryngoscopy or using the video laryngoscope. This facilitates passage of the new tube. It also provides for proper laryngoscope position and airway visualization if the exchange catheter unintentionally or intentionally comes out of the trachea. If this were unsuccessful, intubation using direct laryngoscopy, video laryngoscopy, or flexible fiberoptic bronchoscopy could be attempted. The patient could be oxygenated and ventilated between attempts using bag-mask ventilation or a laryngeal mask airway. Intubation through the LMA could also be considered but would require exchange of the small conventional endotracheal tube for a larger tube in the future. Lastly, a surgical airway could be placed if all attempts failed or the patient became hemodynamically unstable or hypoxic. This could include either an emergent open tracheostomy or percutaneous cricothyroidotomy.

Summary

The best approach to management of a difficult airway in the ICU is prevention and adequate preparation. Ideally, the patient comes to the ICU from the operating room with an endotracheal tube that can be used for the duration of the patient's time on mechanical ventilation or until it is replaced with a tracheostomy appliance via a tracheotomy. If a non-intubated patient with a difficult airway has pending respiratory failure, the planning done far in advance of the event is very important. This includes having oxygen, suction, induction medications, endotracheal tubes, airway equipment, and trained personnel ready and available. It is important to have a flexible approach to managing a challenging airway. This includes quickly moving to alternative options if the initial technique is not successful and having a relatively low threshold to proceeding to a surgical airway especially if the patient is unstable.

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