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Airway Management Issues in the Intensive Care Unit: Revisiting Old Paradigms and Broadening Our Horizons

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ABSTRACT

Airway management in the intensive care setting provides unique challenges that can be quite daunting, even for the most experienced practitioner. Airways are usually intubated for long periods, multiple comorbidities often interfere with "routine" airway management practices, and patients are often physiologically disadvantaged or hemodynamically unstable. Strapped with this calamity, the first responder to a patient with an acutely compromised airway is often someone less experienced with global airway management skills. As anesthesiologists, we are very familiar with the skill sets necessary to handle these predicaments, and as intensivists, we have the fortunate opportunity to share that wealth of information and experience. Airway care in the intensive care unit is a continuum—from elective or emergent intubation, to airway preservation and hygiene, to elective or unintentional extubation. Thus, familiarization with the basics of airway management in routine and "first responder" settings should bolster confidence and greatly improve patient safety and outcomes.

INTRODUCTION

The critical care environment is constantly improvising, adapting, and moving forward. Units have diversified and are now staffed by a multitude of intensivists from different primary specialties, physician extenders, and nurses, also from varied backgrounds. The management schema comes from the unit staff, the primary team, and input from a legion of consultants. Many facilities rely on the intensivist to handle most, if not all, airway management decisions and procedures. Conversely, the anesthesiologist (intensive care unit [ICU] trained or not) may be the primary airway care provider in the ICU. The focus of our involvement in the ICU can be both elective and emergent. Furthermore, it can involve cardiopulmonary resuscitation, intubation, endotracheal tube (ETT) change, tracheostomy placement, fiberoptic bronchoscopy, airway evaluation, or extubation. Recently, collaboration between the critical care staff and the anesthesiology staff has added the brilliant incorporation of education. Topics that are addressed include the following: the distinction between elective and emergent intubation criteria; team organization for an airway emergency and what equipment should be available; physiological and mechanical concepts of preoxygenation, including the techniques involved in proper bag-mask ventilation; concepts related to the American Society of Anesthesiologists (ASA) difficult-airway algorithm; and, finally, the technical skills needed to perform intubations, ETT exchanges, airway evaluations, and safe extubations.

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BODY AND DISCUSSION

Who Ya Gonna Call? Throatbusters! What Constitutes an Airway Emergency?

We are all able to appreciate the situation in which a patient has respiratory distress, but what makes the intubation elective versus emergent, or the airway complexity anticipated versus unanticipated? Finally, in either case, are we prepared? In the operating room, elective and controlled intubation is the standard. Preparation is optimized for the maximum favorable outcome. Even in this prepared environment, however, 10% of all intubations will be difficult, even for the most experienced provider [Stroumpoulis 2009]. This scenario is only further complicated by the remote location (ICU) and the typical lack of supplies available outside of the operating room. Prior to an "off site" intubation, not only is it paramount to assess the airway, it is also necessary to evaluate the entire situation. Assessment should be divided into 3 parts—patient, equipment, and environment.

Patient factors should include the same ones one would assess when taking a history. Table 1 presents an example outline. These items are the minimum to gather in an emergency so that the intubation attempt functions as smoothly as possible.

Equipment and personnel include the items and staff already present in the ICU, as well as those that you bring along. Undoubtedly, some sort of assisted ventilation is already in progress, but a bag-valve-mask device with an oxygen source should be present. Suctioning devices must be readily available at the head of the bed. An emergency airway cart must be readily available for use. In addition, the responding airway team may also bring an airway transport bag to the scene. We will address the contents of each later.

The proper personnel are also essential. Often, "codes" can be a chaotic mass of humanity leading to little or no room to work. Be prepared to take over the situation from the head of the bed and to remove all nonessential personnel. It is

Table 1. Patient Factors Relevant to an Emergency Airway Situation (PAMELA)*

Past medical history and comorbidities	Positioning in the bed	Precautions (universal, contact, respiratory, etc)
Allergies	Medications of interest (pressors, inotropes, sedatives, etc)	Mechanical confounders (cervical collar, halo vest, etc)
Events leading to the situation	Electrolytes	Last meal (full stomach, gastroparesis, tube feeds, postpyloric, etc)
Access (peripheral, PICC, central, etc)	Airway evaluation (dental condition, mouth opening, neck mobility, thyromental distance, neck circumference, facial trauma, facial edema, secretions, bleeding, vomitus)	

*PICC indicates peripherally inserted central catheter.

imperative that the correct medications be given and that the proper tools be provided when they are needed. Physiological capital is at a premium, and hypoxia, hypercarbia, and progressive acidosis will only worsen the outcome. Finally, the environment should be assessed. Is there room to move the bed to access the head? Does the bed function sufficiently to elevate the height or to reposition? Is there adequate lighting? Is the patient being appropriately monitored (frequency) during the resuscitation? Make the environment as conducive to success as possible. Small efforts provide large gains.

A difficult-airway cart or response bag should have a multitude of standard and "rescue" devices commensurate with the ASA difficult-airway algorithm. Multiple laryngoscope handles and blade types should be included. Portable videolaryngoscopy devices, although expensive, are readily available, and their use represents a marked elevation in airway management capabilities. They have a multitude of applications in the intensive care setting, and their use likely minimizes the number of difficult airways that are encountered [Cooper 2005]. Devices to guide the ETT, such as a stylet and bougie, are a mandatory inclusion. Backup nonsurgical emergency ventilation devices, such as a laryngeal mask airway (LMA) (standard or intubating), esophageal tracheal obturator devices (Combitube; Tyco Healthcare, Mansfield, MA, USA), or a transtracheal jet ventilation apparatus, are essential in the "cannot intubate" situation. Surgical airway access is the final stop on the ASA difficult-airway algorithm path. At a minimum, all intensivists should be capable and, more importantly, willing to perform a cricothyroidotomy should the situation present itself. More commonly, intensivists rely on other personnel to perform such tasks; thus, they must have the skill set to support the airway until the "troops arrive." A prepackaged "cric" kit or hospital-based setup is an absolute must to have in a response bag or difficult-airway cart. Finally, common to both a response bag and an airway cart is some method of verifying ETT placement. End-tidal carbon dioxide capnometry devices that assist with avoiding esophageal placement via a change in the pH indicator color are very reliable, provided there is adequate gas exchange and ongoing cellular respiration. Likewise, esophageal detector devices that use (negative) vacuum resistance when aspirated through the ETT provide a method of placement verification independent of gas exchange or perfusion. Both items should be readily available, as well as the necessary equipment for fiberoptic bronchoscopy and for performing a retrograde intubation. Neither of these items would be considered emergent rescue devices, but they have their place for difficult intubations.

Be a Team Player.

Endotracheal intubation is the sine qua non of the definitive airway—but who should perform it, and how should it be accomplished? A 2004 study examined the complications associated with repeated failed laryngoscopic attempts [Mort 2004]. A total of 2536 patients intubated emergently outside of the operating room by all members of the anesthesiology department, including residents, were reviewed for the number of attempts and any resultant complications (hypoxemia, aspiration, esophageal intubation, bradycardia, cardiac arrest, and need for cricothyroidotomy). Success rates were as follows:

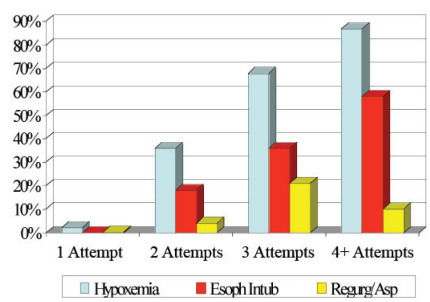

Figure 1. Complication rates compared with intubation attempts. Esoph Intub indicates esophageal intubation; Regurg/Asp, regurgitation/aspiration.

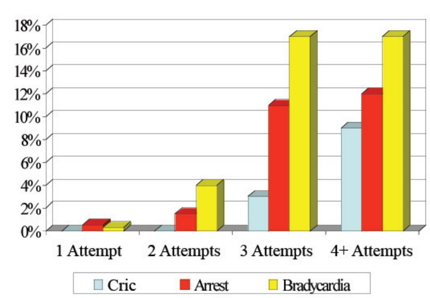

Figure 2. Complication rates compared with intubation attempts. Cric indicates cricothyroidotomy.

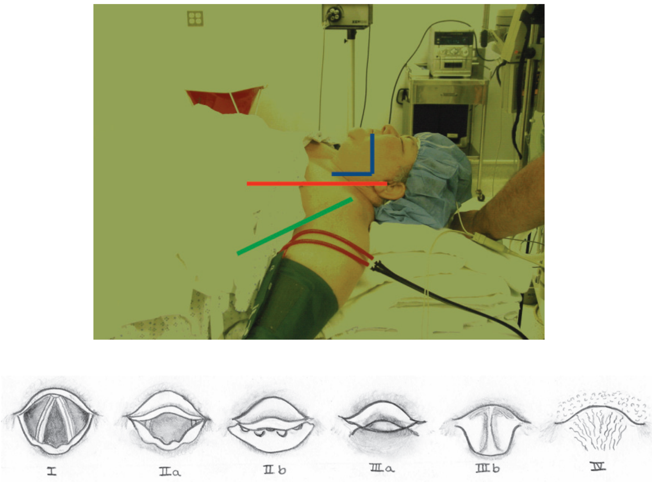

Figure 3. Proper positioning of the difficult airway prior to attempting laryngoscopy. Top, The top angle demonstrates the exaggerated sniffing position, which leads to alignment of the oral, pharyngeal, and laryngeal axes. The middle line shows the optimal height of the ear level with respect to the sternum. The bottom line demonstrates the angle needed to achieve this position. Bottom, Proper alignment of the axes to obtain successful intubation of the trachea. Artwork provided by A. J. Mort.

first attempt, 72%; second attempt, 19%; third attempt, 5%; and ≥4 attempts, 4%. These data were compared with their coincident complication rates (Figures 1 and 2).

It is evident that a direct correlation exists between the number of attempts and the occurrence of any complications, especially those leading to hemodynamic compromise and the need for a surgical airway. The study of Mort [2004] showed a fairly even distribution among anesthesia providers performing the intubations: first-year clinical anesthesia resident (CA1), 17%; CA2, 34%; CA3, 25%; attending physician, 24%. Of note, however, is that all of the resident intubations were supervised by an attending physician. In 2008, Schmidt et al [2008] performed a similar study but evaluated the success rates of resident-performed intubations with respect to attending physician supervision and the resultant complication rate. These investigators demonstrated a 6.1% complication rate for supervised intubations, versus 21.7% for unsupervised intubations (P = .0001). The supervising physicians in both studies were anesthesiologist-intensivists.

These studies point to an important aspect of airway care in the ICU: Experience matters. Given this aspect, the establishment of an airway team with defined roles is essential for improving outcomes. In the study of Schmidt et al [2008], the team consisted of anesthesiology residents on their ICU rotations, the anesthesiologist-intensivist on service, and the respiratory therapist. The team in the Mort study consisted of on-call residents under the supervision of attending anesthesiologists, with the assistance of a respiratory therapist responding to airway emergencies. Since these studies were completed, our institution has taken one further step in the airway process to include a surgical tracheostomy service, staffed by surgical intensivists. The primary reason for its existence is for the placement of surgical airways in elective or emergent situations. Secondarily, they are on call to back up the airway response team should the need arise for a surgically created airway. Both studies highlight the need for consultant assistance from the anesthesiology department to manage airways in the ICU.

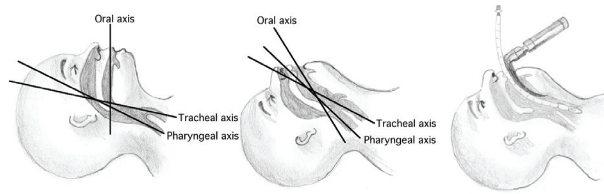

Figure 4. Cormack-Lehane grading system, based on the updated Cook-Yestis modifications. Artwork provided by A. J. Mort.

Where Do We Start? The ABCs of Course!

Prior to the arrival of a definitive airway team, the most important thing to do in an airway emergency is to establish adequate ventilation, ie, oxygenation. Critically ill patients will rapidly desaturate without adequate air movement and oxygenation. In Mort's [2005] study of critically ill patients requiring emergency intubation, patients were randomized to preoxygenation into 2 groups: a group of critically ill patients needing emergent intubation and a group of patients in the operating room undergoing elective open heart surgery. Comparison of baseline and postintubation arterial blood gas measurements demonstrated a substantial increase in arterial PO2 values after 4 minutes of preoxygenation in the elective setting but showed minimal PO2 improvement in the emergent setting. This difference stresses the important point that critically ill patients have marginal physiological reserve and are at increased risk for complications. Noninvasive positive pressure ventilation via continuous positive airway pressure, bilevel positive airway pressure, or bag-valve-mask with 100% oxygen will greatly reduce the occurrence of such complications as hypoxemia, respiratory acidosis, bradycardia, and cardiac arrest [Mort 2005]. Do not forget about the basic positional techniques taught in basic life support and advanced cardiac life support classes, such as the chin lift or jaw thrust, as well as the devices to facilitate ventilation, such as oral and nasal airways. Barring any contraindications to these procedures and equipment, they are quite effective in improving airway patency.

Once it has been determined that ventilation and oxygenation can be achieved, a plan to acquire a definitive airway can be established in a controlled manner. The aforementioned airway team is undoubtedly savvy about most airways, but how can first-pass success rates for emergency tracheal intubations be improved? A letter to the editor regarding the Mort 2005 study [Levitan 2005] made an astute conclusion about the results. He noted that the outcomes reinforced the need for a preplanned strategy to improve first-pass success rates. The establishment and propagation of a defined strategy, however, can be misinterpreted as dogma. Therefore, although a difficult-airway algorithm exists, it should be clear that a single

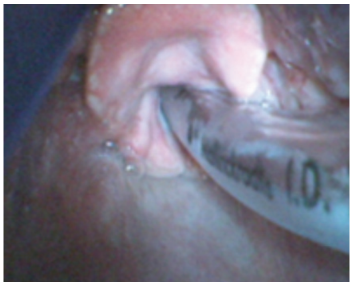

Figure 5. Videolaryngoscopic view of the intubated airway and surrounding tissues.

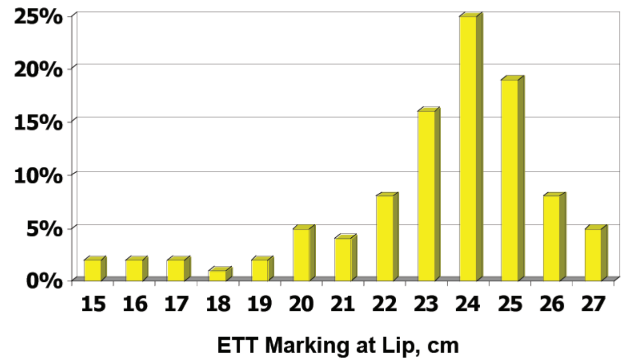

Figure 6. Location of the endotracheal tube (ETT), as determined by the depth marker, in centimeters, adjacent to the dentition.

plan will not fit all patients and that clinical experience is vital [ASA 2003]. For example, since the creation of the 2003 algorithm, videolaryngoscopy has become a widely accepted and highly efficacious tool for emergency airway management but currently has no recognition within the algorithm. A recent study by Serocki et al [2010] compared conventional laryngoscopy and videolaryngoscopy in patients undergoing elective minor surgery and demonstrated that videolaryngoscopy offered a statistically significant improvement in the ability to view the glottis. This work underscores a new paradigm shift for first-pass success with endotracheal intubation; however, the expense of these devices makes their availability less prevalent. Perhaps a more reasonable scheme can be based on common, more readily accessible devices.

We present an example of such a conventional scheme based on the ASA difficult-airway algorithm. Following preparation of all the necessary devices, positioning of the patient, preoxygenation, and induction of anesthesia, laryngoscopy (whether conventional or video) should be attempted. Of note is not to dismiss the importance of proper positioning (see Figure 3). Appropriate positioning will assist with mouth opening, help with axis alignment, and facilitate improved suctioning, placement of an oral airway or LMA, better laryngoscopy views, and the ability to manipulate or cannulate the trachea percutaneously if needed.

Cormack-Lehane views of grade I or II (full or near-full; see Figure 4) should indicate success with conventional intubation methods (with downsizing of the ETT if necessary for passage). A grade III view (epiglottis only) could be assisted with the use of a bougie for ETT advancement. An LMA should serve as the immediate rescue device for any bougie failure. It may also serve as the primary ventilatory method in situations in which bag-mask ventilation can prove difficult (eg, known difficult airway, cervical spine injury, halo vest). As a temporizing measure, a Combitube insertion could be attempted for any device failure. Finally, fiberoptic laryngoscopy/bronchoscopy may be used as a primary method for intubation or in combination with the LMA [Mort 2006].

In 2009, Andersen and Mort presented their work suggesting a change to the present iteration of the ASA difficult-airway algorithm [Andersen 2009]. Emergency intubation attempts that use accessory devices after conventional laryngoscopy failure were compared for 2 time periods, 2000 to 2006 (755 patients) and 2006 to 2009 (445 patients). These periods are delineated by the arrival of videolaryngoscopy capabilities in their facility. Interestingly, the use accessory devices did not change (2000-2006, 40%; 2006-2009, 41%). What did change were the devices implemented. For example, bougie use fell from 28.5% to 9% ($P < .01$), and LMA use decreased from 20% to 7.6% ($P < .01$). Most striking was the manner in which grade IV Cormack-Lehane airways (no view) were managed. In the first period, 90% of these airways were rescued with an intubating LMA or fiberoptic intubation. In the second period, 96% of these views were rescued with videolaryngoscopy. First-attempt success rates improved from 64% to 80% ($P < .01$), and the frequency of the need for >3 attempts was reduced from 8.5% to 4.9% ($P < .01$). As an aside, the rescue device for the 4% of intubation failures in the second period was an LMA, a finding that underscores the need for multiple devices.

Don't Lose That Airway. It's the Only One You've Got! The High-Risk Business of ETT Exchange

ETTs are not foolproof. These devices become obstructed with secretions, they become corrupted because they are chewed on, and they can become defective with excessive manipulation or overinflation of the cuff. Regardless of the cause, an incompetent ETT is unreliable, is dangerous, and needs to be replaced. Maintaining continuous access to the airway by exchanging the ETT over an airway exchange catheter is consistent with ASA guidelines for optimizing patient safety. The difficult-airway patient, however, may still undergo an ETT-exchange procedure that is essentially performed "blindly" because of the anatomic limitations associated with conventional direct laryngoscopy. In 2009, Archambault and Mort presented their findings comparing ETT exchanges performed with a conventional method and those performed with the aid of videolaryngoscopy [Archambault 2009] (Figure 5). First-pass success rates differed (conventional laryngoscopy, 75%; videolaryngoscopy, 100%). Complication rates (hypoxemia, bradycardia, esophageal intubation) also markedly decreased, from 21% with direct laryngoscopy to 5% with videolaryngoscopy. This work further emphasized the importance of videolaryngoscopy in the ICU, but more significantly, it highlighted the need for a skilled airway team to provide an intricate level of care for high-risk procedures.

Table 2. Standard Weaning Criteria*

Appropriate cough and gag reflex	Absence of secretions	Appropriate blood gas parameters
Hemodynamic stability	Adequate oxygenation	Respiratory rate <35/min
PEEP <8 cm	Tidal volume >5 mL/kg	Vital capacity >10 mL/kg
Negative inspiratory force <−20 cm	Appropriate spontaneous breathing trial	Rapid shallow breathing index <105 breaths/min per liter

*PEEP indicates positive end-expiratory pressure.

Table 3. Criteria for Extubation Failure

Increased respiratory rate >30/min, sustained for several hours	Labored breathing demonstrated by fatigue (declining oxygenation)	Rising hypercapnia (declining ventilation)
Hemodynamic instability (increased heart rate)	Altered mental status, agitation	Poor arterial blood gas trends

I Get No Respect, I Tell You, No Respect! Extubation, the Rodney Dangerfield of Airway Management

It goes without saying that the presence of an ETT is an aberration, and therefore the propensity of any individual, patient, or provider is to remove it as soon as possible. It was put there for a reason, however. How do we know when it is safe to take it out? There are several factors at play—physiological, mechanical, and anatomic. High-risk extubations have previously been investigated [Cooper 1995]. That work outlined 2 major components to consider. First, it addressed the difficulty in reestablishing an airway; second, it discussed the ability to tolerate extubation (airway patency, pulmonary status, comorbidities). The second consideration is most often taken into consideration when an extubation is performed. Criteria such as those listed in Table 2, including a rapid shallow breathing index or the success of a spontaneous breathing trial, may all give insight into the preparedness of a patient for extubation.

The first part of Cooper's equation is when an airway team comes in to improve a patient's outcome. The ASA Difficult Airway Task Force recommends that consideration be given to maintaining access to the airway after extubation via an airway catheter [ASA 2003]. Removal of an ETT from a patient in the ICU can present unforeseen challenges because of the higher incidence of traumatic injuries, difficult or traumatized airways, and edematous changes surrounding the improvised airway. Before the actual extubation, however, an experienced airway team can provide a piece of information that has not previously been obtained with any regularity. Work by Keck and Mort has demonstrated that a physical airway evaluation before extubation may add additional information regarding the anatomy of the upper airway and may further improve the safety of extubating a difficult airway [Keck 2009]. Videolaryngoscopy may help predict the success of extubation, because little predictive substantiation exists to address the structural appearance and integrity of the difficult airway as a component of an extubation strategy. Keck and Mort [Keck 2009] demonstrated that direct laryngoscopic views of the airway for this capacity were insufficient to be clinically relevant but that the use of videolaryngoscopy improved the Cormack-Lehane views of grades IV (no view) and IIIa obtained with direct laryngoscopy to grade I or IIa with videolaryngoscopy in 91% of all airways assessed ($P < .005$). The data obtained from this study provide information regarding the periglottic anatomy that could not be assessed until now.

Despite the best intentions, extubation failures still occur. Failure rates range from 0.1% to 25% in the ICU [Provonost 2002]. These failures occur for a multitude of reasons, including neurologic status, cardiopulmonary instability, metabolic and nutritional derangements, or prematurity (Table 3). Keeping in mind the ASA's recommendation to maintain airway control after extubation, Mort presented a study of 87 patients who required emergency reintubation. Two groups of patients were studied, one with an airway catheter left in place after extubation (51 patients, 59%) and the other without a catheter left in place (36 patients, 41%) [Mort 2007]. He discovered that 21 of the 51 patients were reintubated in <2 hours and that 47 of these 51 patients were successfully reintubated with the airway exchange catheter, 41 of whom were reintubated on the first attempt. The conclusion was that an airway catheter provided an increased level of safety.

The use of an airway catheter after extubation may appear to be no better than endotracheal intubation; however, this notion is quite contrary to the actual situation. The use of an airway exchange catheter is well tolerated in most patients. Besides offering a direct path to the subglottic anatomy, the caliber of the device is sufficiently small to permit patients to breathe around it, and it offers very limited interference with phonation. After tolerance, the next most cited resistance to its use is an increased risk for aspiration. In their 1997 study, Loudermilk et al [1997] demonstrated a zero incidence of this phenomenon. Table 4 presents recommendations for the use of an airway catheter after extubation.

Oops, I Did It Again! Inadvertent Partial Extubation

Sometime between intubation and extubation, a question about the depth of ETT placement will arise. Typically, there are 2 scenarios in which this question occurs: right main stem intubation seen on a chest radiograph and a new cuff leak. A cuff leak is due to either actual damage (more common with repeated manipulation) or, more commonly, herniation and dislodgement of the cuff from the trachea. One classic way to try to determine the depth of ETT placement is to look at the marking on the device at the lip. Mort's group reviewed a

Table 4. Recommended Usage Durations for Airway Catheters after Extubation

Difficult airway, no airway edema, no respiratory issues	1-2 h
Difficult airway, potential for airway edema, no respiratory issues	>2 h
Difficult airway, no airway edema, anticipated respiratory issues, multiple extubation failures	>4 h; if previously failed, then use 2 to 3 times the postextubation time for last failure

database of 210 partial extubations [Shapiro 2009]. The study was based on instances in which an anesthesiologist was called to the ICU to evaluate a cuff leak. Each study individual's ETT had an intact pilot balloon with no other associated mechanical defects. The ETT location was noted at the lip (see Figure 6) and then verified by direct visualization via fiberoptic viewing.

How reliable was this method? The study of Mort et al showed that an ETT deeper than 20 cm at the lips/dentition had a 55% chance of being herniated above the vocal cords (extubated). Fiberoptic bronchoscopy provides not only an excellent method for detecting this malady but also the ability to (re)advance the ETT into the trachea. Regarding tip/cuff location, depth markings on the ETT are completely unreliable, and laryngoscopy or bronchoscopy is needed for verification.

CONCLUSIONS

The ICU is a complex and intimidating environment. Even the most trivial problem can be amplified exponentially when it occurs in an ICU patient. Airway emergencies are no exception to this rule. Although a simple plan, such as "failed intubation equals bag-mask, and failed bag-mask equals LMA" will prevent many tragedies, the creation of an airway response team is highly recommended, both for primary management and for surgical backup. Training is at the heart of success in airway endeavors. The ability not only to anticipate problems and remain prepared but also to recognize when one is in over his head is invaluable. Unfortunately, there will be unsuspected difficulties, but they will also be valuable learning opportunities. In addition to ensuring properly trained personnel, response teams must be adequately equipped to respond in the remote ICU environment. For rapid response, it would behoove any ICU to have on hand the basic items covered in the ASA difficult-airway algorithm. Additionally, it is equally beneficial to have the primary airway team outfitted with a rapidly deployable carrier that contains the proper equipment the team members desire and with which they are comfortable. Finally, expanding the roles of the airway consultants within the ICU can only benefit patients. Whether these roles involve bronchoscopy, tracheostomy placement, airway evaluations, or safer extubations, using the service that has been created and using it early (and often) will lead to improved outcomes.

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