Airway Management in Critical Illness

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Airway management in the ICU can be complicated due to many factors including the limited physiologic reserve of the patient. As a consequence, the likelihood of difficult mask ventilation and intubation increases. The incidence of failed airways and of cardiac arrest related to airway instrumentation in the ICU is much higher than that of elective intubations performed in the operating room. A thorough working knowledge of the devices available for the management of the difficult airway and recommended rescue strategies is paramount in avoiding bad patient outcomes. In this review, we will provide a conceptual framework for airway assessment, with an emphasis on assessment of the patient with limited cervical spine movement or injury and of morbidly obese patients. Furthermore, we will review the devices that are available for airway management in the ICU, and discuss controversies surrounding interventions like cricoid pressure and the use of muscle relaxants in the critically ill patient. Finally, strategies for the safe extubation of patients with known difficult airways will be provided.

Expertise in airway management is an important skill for any health-care provider who is caring for critically ill patients. Due to advances in training and technology, elective airway management within the confines of the operating room is associated with very low rates of complications. These observations are in stark contrast to emergent airway management in the ICU. Complication rates in the ICU environment are much higher due to the limited physiologic reserve and comorbidities of the patient, as well as the inability, in the majority of cases, to perform a thorough evaluation of the patient’s anatomy prior to airway instrumentation. Furthermore, some of the induction agents that are suitable for airway management in the elective setting may be contraindicated in critically ill patients, further limiting the options for airway instrumentation.

In a systematic study of complications associated with airway management in the ICU, Schwartz and colleagues reported major complications in a significant number of patients. Among the problems encountered were difficult intubations (DIs) [8%], esophageal intubations (8%), and pulmonary aspiration (4%), and an associated mortality rate of 3%. There was a significant correlation between the presence of hypotension at the time of intubation and cardiac arrest in this study. Kollef et al reviewed retrospectively over a 12-month period 278 patients requiring endotracheal intubation in an acute care military hospital. They found that almost 10% of patients (22 patients) had at least one significant endotracheal tube (ETT) misplacement,
and 23% of these individuals experienced serious complications. A recent prospective, observational multicenter study performed in French ICUs found at least one severe complication in 28% of all intubations, with an overall rate of cardiac arrest related to endotracheal intubation in the ICU of 2%. The presence of acute respiratory failure and the presence of shock as the indication for endotracheal intubation were independent risk factors for complications, whereas supervision by a senior physician appeared to have a protective effect. In a study on the frequency and outcomes of unplanned endotracheal extubations in a university trauma-surgical ICU, difficulty with reintubation (multiple or prolonged attempts) or need for a fiberoptic bronchoscope was a common occurrence (20%). The authors concluded that highly skilled airway management is necessary to avoid adverse outcomes related to reintubation.

The implementation of training programs for ICU staff, immediate access to advanced airway devices, and knowledge and incorporation of the American Society of Anesthesiologists (ASA) difficult airway algorithm (DAA) [Fig 1] may decrease the incidence of serious complications related to airway instrumentation in the ICU. In a retrospective review of 3,035 critically ill patients undergoing emergency airway management, Mort analyzed two time periods, 1990 to 1995 and 1995 to 2002, after the implementation of a protocol requiring the availability of advanced airway equipment at the bedside. Cardiac arrest within 5 min of intubation occurred in 2% of the patients overall. However, the rate was reduced by 50% between the first and the second time period analyzed (1990 to 1995, 2.8%; 1995 to 2002, 1.4%).

In this review, we assume that the reader has a working knowledge of airway anatomy and of the technique for routine endotracheal intubation. Accordingly, we consider aspects of the use of medications, strategies for airway assessment prior to intubation, and some technical approaches to airway management in critically ill patients. Controversies surrounding airway management such as rapid sequence intubation (RSI), the merit of cricoid pressure and the sniffing position, as well as the risks associated with the use of muscle relaxants will be discussed. Furthermore, we will provide strategies for the safe extubation of the patient with a known difficult airway.

**AIRWAY ASSESSMENT**

Assessing a patient’s airway prior to performing a potentially difficult endotracheal intubation is challenging in the best of circumstances; in the critically ill patient with severe respiratory distress or failure, it may be virtually impossible. There is some controversy as to what assessment tool has the best predictive value for DI; however, a focused and brief examination of the patient’s airway may substantially influence the strategy for airway management and the success of the procedure. An initial step in assessment is to determine the need for invasive vs noninvasive ventilatory support. If the patient needs invasive ventilatory support, the individual should quickly be assessed for (1) the risk for difficult mask ventilation and (2) the risk for DI. Independent risk factors for difficult mask ventilation in the elective setting include age of > 55 years, body mass index of > 26 kg/m², lack of teeth, male gender, Mallampati class 4 airway, the presence of a beard, and a history of snoring. Whether these factors can be extrapolated to critically ill patients is unknown; however, it seems prudent to include them into the analysis in order to decrease the likelihood of a “cannot intubate, cannot ventilate” scenario. Several clinical indicators for DI have been validated (Table 1). While the positive predictive values of these tests alone or in combination are not particularly high, a straightforward intubation can be anticipated if the test results are negative.

For a recent review on the common clinical predictors of DI see the study by Reynolds and Heffner. Since only about 30% of airways in the emergency setting can be evaluated in this fashion, additional evaluation methods have been devised. Murphy and Walls have introduced the LEMON (ie, Look, [e]Mallampati class, Obstruction, and Neck mobility) airway assessment method to stratify the risk of DI in the emergency department. Furthermore, Reed et al were able to demonstrate that patients with large incisors, a reduced mouth opening, and a reduced thyroid-to-floor-of-mouth distance are more likely to have a poor airway grade during laryngoscopy.

**PREPARATION FOR ENDOTRACHEAL INTUBATION**

Being prepared for unforeseen complications during endotracheal intubation is of prime importance when instrumenting airway of a critically ill patient. Furthermore, conditions for intubation should be as close to ideal as possible in a busy ICU environment, and should include adequate personnel, optimal patient positioning and lighting, and the necessary equipment for endotracheal intubation. A supply of 100% oxygen, a well-fitting mask with attached bag-valve device (which should be checked for valve competency prior to use), suctioning equipment, a Magill forceps, and oral and nasal airways should be immediately available. The bed should be positioned...
at the proper height with the wheels locked, and a laryngoscope with blades of various sizes (straight and curved) should be available. The laryngoscope batteries and light should be checked on a routine basis.

Traditional teaching recommends placing the patient in the "sniffing" position, in which the neck is flexed and the head is slightly extended about the atlantooccipital joint in order to align the oral, pharyngeal, and laryngeal axes. An MRI study has called this concept into question, as the alignment of the three axes could not be achieved in any of the three positions tested (ie, neutral, simple head extension, and the sniffing position). In a randomized
study\textsuperscript{15} conducted in general surgery patients, simple head extension was as effective as the sniffing position in facilitating tracheal intubation. Nonetheless, the sniffing position appears to provide an advantage in obese patients and in patients who have limited head extension. The utility of the sniffing position for intubations outside of the operating room is unknown. Preoxygenation prior to airway instrumentation is important and is usually facilitated with the administration of oxygen via a nonrebreathing face mask and bag-valve mask device. It is important to note, however, that patients with respiratory failure due to cardiopulmonary disease may not have an adequate response to conventional preoxygenation. Mort\textsuperscript{16} was able to demonstrate that only 50\% of patients in this category have an increase in PaO\textsubscript{2} of \textasciitilde{}5\% above baseline values with conventional preoxygenation of 4 min duration. To address this problem, Baillard and coworkers\textsuperscript{17} conducted a prospective, randomized study in a cohort of medical/surgical ICU patients comparing preoxygenation prior to endotracheal intubation with the use of noninvasive positive-pressure ventilation (NIPPV) to a bag-valve mask device for 3 min duration. The application of NIPPV ensured better pulse oximetric saturation and PaO\textsubscript{2} values during tracheal intubation and up to 5 min into the postintubation period compared to the conventional preoxygenation method.\textsuperscript{17} For a complete checklist of the supplies needed for endotracheal intubation, see Table 2.

After successful endotracheal intubation, it is of vital importance to confirm proper tube positioning. Methods to ascertain the position of the tube within the trachea include bilateral auscultation of the chest and measurement of end-tidal carbon dioxide by standard capnography if available, or by means of colorimetric chemical detection of end-tidal carbon dioxide (eg, Easy Cap II; Nellcor, Inc; Pleasanton, CA). The colorimetric detector is attached to the proximal end of the ETT and changes color on exposure to carbon dioxide. An additional method for detecting esophageal intubation uses a bulb that attaches to the proximal end of the ETT.\textsuperscript{18} When squeezed, the bulb will reexpand if it is in the trachea, but will remain collapsed with esophageal placement of the ETT. None of these methods is absolutely reliable; fiberoptic bronchoscopy is the only way to document ETT placement with absolute certainty. Given the potentially serious conse-

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**Table 1—Components of the Preoperative Airway Physical Examination**

<table>
<thead>
<tr>
<th>Airway Examination Component</th>
<th>Nonreassuring Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of upper incisors</td>
<td>Relatively long</td>
</tr>
<tr>
<td>Relation of maxillary and mandibular incisors during normal jaw closure</td>
<td>Prominent “overbite” (ie, maxillary incisors anterior to mandibular incisors)</td>
</tr>
<tr>
<td>Relation of maxillary and mandibular incisors during voluntary protrusion</td>
<td>Patient cannot bring mandibular incisors anterior to (in front of) maxillary incisors</td>
</tr>
<tr>
<td>Interincisor distance</td>
<td>\textless{} 3 cm</td>
</tr>
<tr>
<td>Visibility of uvula</td>
<td>Not visible when tongue is protruded with patient in sitting position (eg, Mallampati class \textgreater{} II)</td>
</tr>
<tr>
<td>Shape of palate</td>
<td>Highly arched or very narrow</td>
</tr>
<tr>
<td>Compliance of mandibular space</td>
<td>Stiff, indurated, occupied by mass, or nonresilient</td>
</tr>
<tr>
<td>Thyromental distance</td>
<td>Less than three ordinary finger breadths</td>
</tr>
<tr>
<td>Length of neck</td>
<td>Short</td>
</tr>
<tr>
<td>Thickness of neck</td>
<td>Thick</td>
</tr>
<tr>
<td>Range of motion of head and neck</td>
<td>Patient cannot touch tip of chin to chest or cannot extend neck</td>
</tr>
</tbody>
</table>

*This table displays some findings of the airway physical examination that may suggest the presence of a difficult intubation. The decision to examine some or all of the airway components shown in this table depends on the clinical context and the judgment of the practitioner. The table is not intended as a mandatory or exhaustive list of the components of an airway examination. The order of presentation in this table follows the “line of sight” that occurs during conventional oral laryngoscopy. Reprinted with permission from Christie et al.\textsuperscript{5}*

**Table 2—Equipment Needed for Intubation**

<table>
<thead>
<tr>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply of 100% oxygen</td>
</tr>
<tr>
<td>Face mask</td>
</tr>
<tr>
<td>Bag valve device with PEEP valve</td>
</tr>
<tr>
<td>End-tidal CO\textsubscript{2} detector</td>
</tr>
<tr>
<td>Suction equipment</td>
</tr>
<tr>
<td>Suction catheters</td>
</tr>
<tr>
<td>Large-bore tonsil suction apparatus (Yankauer)</td>
</tr>
<tr>
<td>Stylet</td>
</tr>
<tr>
<td>Magill forceps</td>
</tr>
<tr>
<td>Oral airways</td>
</tr>
<tr>
<td>Nasal airways</td>
</tr>
<tr>
<td>Laryngoscope handle and blades (curved, straight, various sizes)</td>
</tr>
<tr>
<td>Endotracheal tubes (various sizes)</td>
</tr>
<tr>
<td>Tongue depressors</td>
</tr>
<tr>
<td>Syringe for cuff inflation</td>
</tr>
<tr>
<td>Headrest</td>
</tr>
<tr>
<td>Supplies for vasoconstriction and local anesthesia</td>
</tr>
<tr>
<td>Tape</td>
</tr>
<tr>
<td>Tincture of benzoin</td>
</tr>
</tbody>
</table>

*PEEP = positive end-expiratory pressure.*
quences of esophageal intubation, auscultation of the chest should always be combined with one additional test. Furthermore, a postintubation chest radiograph should always be obtained. Some of the most common complications of endotracheal intubation are listed in Table 3; for a comprehensive review on the subject see Hagberg et al.19

The following two patient populations deserve special mention: the morbidly obese patient; and the critically ill patient with known or suspected cervical spine injuries. In a recent review20 of 4,000 patients in the Australian Incident Monitoring Study, obesity and limited neck mobility were among the most common anatomic factors contributing to DI and/or a failed airway.

Morbid Obesity

Morbidly obese patients are more prone to hypoxemia than individuals of normal weight due to reductions in expiratory reserve volume, FVC, FEV1, functional residual capacity, and maximum voluntary ventilation.21 Due to body habitus, laryngeal exposure may be difficult. In addition, since repositioning a morbidly obese patient may be impossible if difficulties during laryngoscopy and/or intubation are encountered, careful patient positioning and choice of airway management is vitally important. Collins and coworkers22 compared the difference between the “sniff” and “ramped” positions in morbidly obese patients undergoing elective bariatric surgery with respect to the quality of the laryngeal view obtained. They were able to demonstrate significantly better laryngeal views when a ramped position was achieved by arranging blankets underneath the patient’s body and head until horizontal alignment was achieved between the external auditory meatus and the sternal notch.22 It is conceivable that this would also improve laryngeal exposure in morbidly obese patients in the ICU setting. If there is concern about the adequacy of the mask airway to maintain oxygenation, use of an awake fiberoptic intubation (FOI) technique should always be considered.

C-Spine Injuries and Immobility

Managing the airway of a patient with limited neck mobility or cervical spine injury on an emergent basis requires careful planning and significant experience in order to avoid morbidity and mortality. Retrospective studies23–27 have suggested that neurologic deterioration in patients with cervical spine injuries is uncommon after airway management, even in high-risk patients undergoing urgent endotracheal intubation. These studies23–27 are limited, however, by their small sample size. While not all cervical spine injuries result in clinical instability, the results of initial radiographic studies in critically ill patients are often unknown at the time the airway has to be managed, and cervical spine precautions during airway instrumentation should be maintained. The reader is referred to a comprehensive review on airway management after cervical spine injury.29 Manual in-line immobilization during endotracheal intubation appears to be safe and effective for the prevention of morbidity that is related to airway instrumentation in patients with cervical spine injuries. Removing the anterior portion of the cervical collar while maintaining manual in-line immobilization is associated with less spinal movement than cervical collar immobilization during laryngoscopy and therefore should be routinely performed.29,30 Furthermore, there is evidence suggesting that cricoid pressure does not result in deleterious cervical movement in a patient with an injured upper cervical spine.31 While there is no evidence in the literature to demonstrate the superiority of one mode of endotracheal intubation over the other, the authors of this review believe that awake FOI techniques should be strongly considered in the setting of limited neck mobility and cervical spine injuries. For patients with cervical stabilization in a halo device, the ability to perform a surgical airway, should conventional attempts for airway management fail, may be lifesaving. Conditions other than trauma that are associated with a decreased range of motion include any cause of degenerative disk disease (e.g., rheumatoid arthritis, osteoarthritis, and ankylosing spondylitis) and age > 70 years. Caution should also be exercised in patients with previous cervical spine instrumentation that may result in unanticipated difficult airway, necessitating fiberoptic-guided endotracheal intubation32 or intubation through a laryngeal mask airway (LMA).

<table>
<thead>
<tr>
<th>Complications</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traumatic complications</td>
<td>Cornal abrasion</td>
</tr>
<tr>
<td></td>
<td>Dental damage</td>
</tr>
<tr>
<td></td>
<td>Perforation or laceration of pharynx, larynx, trachea, or esophagus</td>
</tr>
<tr>
<td></td>
<td>Vocal cord injury</td>
</tr>
<tr>
<td></td>
<td>Dislocation of an arytenoid cartilage</td>
</tr>
<tr>
<td></td>
<td>Mainstem bronchus intubation</td>
</tr>
<tr>
<td>Hemodynamic and other complications</td>
<td>Aspiration</td>
</tr>
<tr>
<td></td>
<td>Hypotension</td>
</tr>
<tr>
<td></td>
<td>Arrhythmias</td>
</tr>
<tr>
<td></td>
<td>Hypoxia</td>
</tr>
<tr>
<td></td>
<td>Hypercarbia</td>
</tr>
<tr>
<td></td>
<td>Laryngeal spasm</td>
</tr>
<tr>
<td></td>
<td>Bronchospasms</td>
</tr>
</tbody>
</table>
RSI and Muscle Relaxants

Since the majority of ICU patients requiring endotracheal intubation should be considered to have a full stomach, securing the airway with a rapid-sequence intubation (originally termed rapid sequence induction in the operating room setting) therefore seems logical. There are, however, several caveats to consider before embarking on an airway management strategy that may leave very few options short of surgical airway intervention should the intensivist unexpectedly encounter a “cannot intubate, cannot ventilate scenario.” Furthermore, there are several contraindications to the use of succinylcholine in critically ill patients, thus eliminating the fastest and most reliable muscle relaxant that is used to facilitate rapid sequence endotracheal intubation (see the next section).

Prior to administering drugs to facilitate airway management in the ICU, a decision should be made about whether spontaneous breathing should be preserved or ablated during endotracheal intubation.

**Controversies in RSI**

The classic teaching of RSI includes the application of cricoid pressure to avoid the regurgitation of gastric contents into the lung. Initially described by Sellick in 1961, this concept has been questioned by an MRI study of awake volunteers. Smith et al were able to demonstrate that the esophagus was lateral to the larynx in >50% of the subjects. Moreover, cricoid pressure increased the incidence of an unoccluded esophagus (by 50% and caused airway compression of >1 mm in 81% of the subjects studied. There are, however, cadaver studies demonstrating the efficacy of cricoid pressure and clinical studies showing that gastric insufflation with air during mask ventilation is reduced when cricoid pressure is applied. While cricoid pressure may or may not decrease the risk of aspiration, there is evidence that it may worsen the quality of laryngeal exposure. In a randomized intervention study on human cadavers involving emergency medicine physicians, a total of 1,530 sets of comparative laryngoscopies were performed by 104 participants. In this study, bimanual laryngoscopy (external laryngeal manipulation by the endoscopist with the free hand) improved the view compared to the application of cricoid pressure, application of back, upward, and right pressure on the thyroid cartilage (also referred to as BURP), or no manipulation. Cricoid pressure and back, upward, and right pressure on the thyroid cartilage frequently worsened the view on laryngoscopy. In a critical appraisal of the available literature, including 241 articles on the topic of cricoid pressure, Butler and Sen concluded that there is little evidence to support the widely held belief that the application of cricoid pressure reduces the incidence of aspiration during RSI. As the application of cricoid pressure may have adverse effects, a careful analysis of the risks and benefits should be performed on an individual basis until more systematic studies are performed.

**Choices of Drugs**

Emergent airway management in the ICU is frequently complicated by the patient’s limited physiologic reserve, which will often manifest as hypotension immediately after tracheal intubation. The exact incidence of morbidity and mortality related to airway management facilitated by the use of IV induction agents in the ICU is unknown; however, it is likely to be underreported. Several comprehensive reviews on pharmacologic agents used for airway management in the ICU have been published; we will therefore provide a brief overview of commonly used agents and discuss controversies surrounding their use.

**Propofol**

Propofol is a popular hypnotic agent for several reasons. It is associated with pleasant emergence and little hangover, is readily titratable, and has more rapid onset and offset kinetics than midazolam. In patients with cardiac comorbidities and limited physiologic reserve, it can be associated with significant hypotension, thus limiting its use in this patient population. In an analysis of 4,096 patients undergoing general anesthesia, Reich and coworkers reported that ASA physical status class III to V, baseline mean arterial pressure of <70 mm Hg, age >50 years, and the use of propofol were statistically significant multivariate predictors of hypotension. In the 2,406 patients with retrievable outcome data, prolonged postoperative hospital stay and/or death were more common in the patient group that experienced hypotension. While propofol provides superior conditions for endotracheal intubation without muscle relaxants compared to sodium pentothal, it induces more hypotension and bradycardia in patients undergoing elective surgical procedures. This adds to previous evidence indicating that propofol may not be safe for high-risk patients with known cardiac dysfunction. Whether or not data obtained in the operating room environment can be extrapolated to the ICU setting is unknown; however, the independent risk factors cited previously certainly apply to the majority of patients who are in need of emergent airway management in the ICU.
Etomidate

Etomidate has onset and offset pharmacokinetic characteristics that are similar to propofol, and lacks significant effects on myocardial contractility (even in the setting of cardiomyopathy), which make it one of the preferred induction agents for airway management in critically ill patients. When it was studied in a heterogeneous group of patients undergoing RSI in the emergency department, etomidate provided good intubation conditions with very few hemodynamic derangements, even in those patients with low BP prior to airway instrumentation. Nevertheless, the role of etomidate in clinical practice is in question due to its effect on adrenal production of steroids. Etomidate inhibits adrenal steroidogenesis through the inhibition of mitochondrial hydroxylase, both after a single dose and continuous administration. Based on the available evidence, the use of etomidate in critically ill patients with sepsis and septic shock should be discouraged. If patients who are in septic shock receive etomidate, corticosteroid supplementation to prevent unnecessary deaths is recommended. Since the adrenal suppression by the drug lasts longer than previously estimated (up to 72 h), some authors have questioned the use of etomidate in critically ill patients altogether.

Ketamine

Ketamine is unique among the hypnotic agents in that it has analgesic, sedative, and amnestic effects. It has a slower onset and offset compared to propofol or etomidate following IV infusion, and stimulates the cardiovascular system (ie, raises heart rate and BP by direct stimulation of the CNS). In the usual dosage, ketamine decreases airway resistance. Whether ketamine, when administered as an adjunct during emergent airway management in the ICU, provides adequate intubation conditions has not been studied in a systematic fashion. When compared to sodium pentothal in a dose of 5 mg/kg, ketamine (2.5 mg/kg) will provide superior intubation conditions 1 min after the administration of rocuronium (0.6 mg/kg) in the elective surgery setting. These findings are supported by a more recent prospective, randomized, controlled clinical trial in which the administration of ketamine resulted in excellent intubation conditions in a significantly higher proportion of elective surgery patients when compared to the administration of sodium pentothal. Ketamine also appears to be a useful adjunct to etomidate when RSI is performed with rocuronium. The combination of ketamine with etomidate and rocuronium resulted in superior intubation conditions in a prospective, randomized clinical trial of patients undergoing elective surgery when compared to the combination of etomidate, fentanyl, and rocuronium, or etomidate with rocuronium, respectively. In the ICU, this combination may be useful for treating hemodynamically unstable patients with contraindications to the use of succinylcholine who are in need of emergent airway management facilitated by a neuromuscular blocker. The use of ketamine in patients with increased intracranial pressure is controversial; in this setting, it should be administered only after a careful risk-benefit analysis.

Dexmedetomidine

Dexmedetomidine is a centrally acting, selective α2 receptor agonist that has been approved for use in the United States for the short-term sedation of critically ill patients. The drug may be useful for the awake, fiberoptic management of the airway in the ICU due to its analgesic, anxiolytic, and sedative effects without causing clinically significant respiratory depression. There have been case reports documenting the usefulness of dexmedetomidine for awake FOI in the operating room setting among patients undergoing elective surgery; however, no data are available regarding its use as an adjunct to airway management in the ICU.

Neuromuscular Blocking Agents

Succinylcholine: The use of succinylcholine (1 mg/kg IV) will result in excellent intubation conditions in < 1 min. Unless there are contraindications, it is the drug of choice when the airway must be secured quickly (ie, in the patient with a full stomach or with symptomatic gastroesophageal reflux). The drug may trigger malignant hyperthermia in genetically susceptible persons, and can cause a malignant rise in extracellular potassium concentration in patients with major acute burns, upper or lower motor neuron lesions, prolonged immobility, massive crush injuries, and various myopathies. Infrequently, the use of succinylcholine can be associated with prolonged paralysis due to decreased plasma cholinesterase activity. Caution is also advised concerning its use in patients with open globe injuries, renal failure, and serious infections, and in near-drowning victims. Patients who are in a state of prolonged immobility are at a heightened risk of hyperkalemia when exposed to succinylcholine due to changes in the regulation and distribution of acetylcholine receptors during a course of critical illness, in particular the postsynaptic up-regulation of nicotinic acetylcholine receptors and the expression of immature receptors. The up-regulation of receptors during periods of immobilization have been...
described as early as 6 to 12 h into the disease process. Therefore, we recommend avoiding the use of succinylcholine in critically ill patients beyond 24 h in those with burns and spinal cord injury, and beyond 48 to 72 h of immobilization and/or denervation. For a comprehensive review on succinylcholine-induced hyperkalemia, see the article by Martyn and Richtsfeld.64

**Rocuronium:** Of the currently available non-depolarizing neuromuscular blocking agents, rocuronium has the fastest onset of action and represents the only alternative to succinylcholine for use during RSI. In a dose of 0.8 to 1.2 mg/kg, rocuronium will provide excellent intubation conditions within 60 s. When compared to succinylcholine in a randomized, clinical trial65,66 on tracheal intubation in emergency cases, the two agents were equivalent with respect to acceptable intubation conditions and the number of failed intubation attempts. Succinylcholine (1 mg/kg) provided superior intubation conditions when compared to rocuronium in this trial; however, the dose of rocuronium that was used (0.6 mg/kg) was on the low end of the dosage range recommended for RSI.65,66 These results were confirmed by a more recent trial67 demonstrating superior intubation conditions for RSI with the use of succinylcholine (1 mg/kg) compared to rocuronium (0.6 mg/kg), but no difference in the rate of adverse airway effects.67 A metaanalysis68 by the Cochrane Collaborative Group concluded that the intubating conditions achieved with the use of rocuronium are not statistically different from those achieved with succinylcholine when propofol is used as an induction agent.

**Ways To Establish the Airway**

Three principal modalities are available for the delivery of mechanical ventilation to a critically ill patient. These are NIPPV via face mask, extraglottic airway devices (eg, various LMAs, an esophageal-tracheal device [Combitube ETC; Tyco-Healthcare-Kendall USA; Mansfield, MA], or a perilaryngeal airway), or the endotracheal route (eg, ETT or tracheostoma). The most commonly practiced technique for endotracheal intubation is direct laryngoscopy with either a curved blade (Macintosh blade) or a straight blade (Miller blade) of various sizes. The choice of blade shape is a matter of personal preference; however, one study69 has suggested that less force and head extension are required when performing direct laryngoscopy with a straight blade. With respect to blade material, plastic single-use blades are inexpensive and carry a lower risk of infection when compared to metal reusable blades. Nevertheless, their use in a critical care setting should be discouraged. In a prospective randomized trial70 of 284 adult patients undergoing general anesthesia requiring RSI, plastic laryngoscope blades were less efficient than metal blades, resulting in a significantly higher rate of failed intubation on the first attempt. Several laryngoscope blades to facilitate Dls have been introduced in the past. These include, but are not limited to, the McCoy angulated blade, the Dorges blade, the Viewmax laryngoscope blade (Rusch; Duluth, GA) with a patented lens system, as well as blades augmented by video or fiberoptic capabilities (eg, the Bullard Laryngoscope; ACMI: Southborough, MA; or the GlideScope; Veri-thon; Bothell, WA; or the WuScope; Achi Corp; San Jose, CA). There are no data on the utility of these tools for airway management in the ICU. In a trial comparing the alternative blades with standard blades on a human patient simulator, the Dorges and McCoy blades did not perform any better than the standard Macintosh blade either in easy or difficult tracheal intubation conditions.71 However, there are data from patients undergoing elective or emergent intubation in the operating room as well as from trials using cadavers and mannequins (some in the setting of limited neck mobility) suggesting that better glottic visualization is achieved with video-assisted or fiberoptic devices than with conventional blades.30,72–79

Extraglottic airway devices for supralaryngeal ventilation can be further divided into cuffed, orally inserted hypopharyngeal airways (ie, various forms of LMA) and cuffed orally inserted esophageal airways (esophageal tracheal combitube).80 Of the hypopharyngeal devices for ventilation, the LMA-Fastrach (LMA North America, Inc; San Diego, CA) appears to be particularly useful for airway management in the ICU due to its unique design, which allows the mask to be used as a conduit for endotracheal intubation. This device was recently modified, and is now available with an integrated fiberoptic system and a detachable monitor (LMA Ctrach; LMA North America, Inc) allowing for endotracheal intubation under direct vision without the use of a fiberoptic bronchoscope. In a study of 254 patients with difficult-to-manage airways, including patients with Cormack-Lehane grade 4 views, patients with immobilized cervical spines, patients with airways distorted by tumors, surgery, or radiation therapy, and patients wearing stereotactic frames, the insertion of the LMA-Fastrach was accomplished in three or fewer attempts in all patients. The overall success rates for blind and fiberoptically guided intubations through the LMA-Fastrach were 96.5% and 100.0%, respectively.81 When studied in morbidly obese patients undergoing elective surgical procedures, the rate of
successful tracheal intubation with the LMA-Fastrach was 96.3%. Recent data have suggested that the new LMA CTrach system has potential advantages over the LMA-Fastrach and can be very useful in the management of the difficult airway. When a difficult airway is recognized prior to the administration of induction agents, an awake, FOI may be the best option; however, other modalities of awake intubation are possible (eg, blind oral or nasal intubation, or retrograde techniques). Fiberoptic bronchoscopy may be particularly useful when upper airway anatomy has been distorted by tumors, trauma, endocrinopathies, or congenital anomalies. Furthermore, it is useful in accident victims in whom a question of cervical spine injury exists and the patient’s neck cannot be manipulated. If the airway has to be secured via FOI in an emergent fashion, the use of a topical anesthesia seems preferable to regional nerve blockade.

**Rescue Strategies**

Should initial attempts at endotracheal intubation fail, an alternative strategy for providing ventilation to the patient, and ultimately for securing the airway, must be in place. The implementation of the ASA DAA in the critical care setting is logical and, according to one analysis, may have decreased the number of failed airways in the ICU environment. Since this airway algorithm was originally developed as a tool for anesthesia providers in the operating room, some minor adaptations for the ICU setting should be considered (Fig 2). While assessments of the likelihood of successful intubation and the clinical impact of basic management problems remain the same, critically ill patients in respiratory failure will almost certainly have less tolerance for periods of apnea than patients with unanticipated difficult airways in the operating room. The return to spon-

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**Algorithm for airway management in the ICU**

1. **Invasive airway management**
   - Potential for DMV and/or DI
   - Fails, mask ventilation inadequate
   - Ablation vs preservation of SB, With or without NMBA
   - Fails, mask ventilation adequate
   - Intubating-, video-assisted-, or classic LMA as bridge for definitive airway mgt
   - Supralaryngeal ventilation as conduit for intubation
   - Yes, pt in respiratory arrest
   - Yes, adequate physiologic reserve
   - Primary awake technique (FOI, nasotracheal)
   - NIPPV
   - Non-invasive airway management
   - Call senior physician for assistance
   - Airway management necessary

2. **ASA DAA emergency pathway**

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**Figure 2.** Algorithm for airway management in the ICU. SB = spontaneous breathing; NMBA = neuromuscular blocking agent; DMV = difficult mask ventilation; pt = patient.
taneous ventilation is an important exit strategy for intubation in the operating room during elective surgery. In the ICU, this is often impossible due to mechanical failure and the limited physiologic reserves of the patient. Strategies for airway management in the emergency pathway of the ASA DAA include alternative means to provide ventilation (e.g., the LMA-Fasttrach described in the previous section, as well as the Combitube; Tyco-Healthcare-Kendall USA; Mansfield, MA). The LMA can also be used as an intubation conduit and has been reported as a successful bridge to percutaneous tracheostomy in a case of failed airway in the ICU.85 The Combitube combines the features of an ETT and an esophageal obturator airway, and reduces the risk of aspiration. The use of these devices can be learned easily by personnel who are unskilled in airway management.86 Other devices that are suitable for noninvasive rescue strategies include the gum elastic bougie or an airway exchanger catheter (Cook Critical Care; Bloomington, IN). These devices may be useful in a situation in which the glottis can be only partially visualized and the insertion of the ETT into the trachea is unsuccessful. In a randomized study28 of 60 patients undergoing elective intubation with the application of cricoid pressure, the use of a gum elastic bougie was more effective than a regular stylet to facilitate intubation. Another tool included in the ASA DAA emergency pathway is retrograde endotracheal intubation, which entails passing a wire through the cricoid ring and the vocal cords.87 To overcome the complications encountered was the inability to pass the ETT through the vocal cords.87 To overcome this problem, Lenfant and coworkers88 have recently developed a modification of the technique in a human cadaver study. Insertion of the hollow guiding catheter is inserted in a cephalad direction over the guidewire, the guidewire is removed, and the ETT is then advanced antegrade over the guiding catheter into the trachea. A commercial kit for the procedure is available (e.g., Cook Critical Care). Success rates for the procedure vary. In a review87 of 1,368 patients undergoing endotracheal intubation in the emergency department, the authors found that retrograde endotracheal intubations were attempted in 8 patients, of which only four were successful. Among the complications encountered was the inability to pass the ETT through the vocal cords.87 To overcome this problem, Lenfant and coworkers88 have recently developed a modification of the technique in a human cadaver study. Insertion of the hollow guiding catheter antegrade through the ETT into the trachea prior to removal of the guidewire significantly increased the success rate from 69%, using the classic technique, to 89%, using the modified technique.88 It should be noted, however, that each provider participating in the study had previously performed at least 10 successful procedures in a cadaver, suggesting that this strategy should be carried out by experienced providers only. Should all alternative and noninvasive strategies to provide ventilation fail, a surgical airway has to be established. The two principal choices are cricothyroidotomy and tracheostomy, either in a percutaneous or open surgical fashion. In a study38 comparing surgical cricothyroidotomy (Portex cuffed device; Smiths Medical Ltd; Hythe, UK) and wire-guided cricothyroidotomy (cuffed and uncuffed version of Melker-set; Cook Critical Care) in an airway mannequin and artificial lung model, the cuffed devices provided more effective ventilation and tidal volumes. Furthermore, the surgical method was found to be quicker than the wire-guided approach (mean time to first breath, 44.3 vs 87.2 s, respectively) but may have a higher failure rate in inexperienced hands.89 Few data are available on the utility of percutaneous dilatational tracheostomy (PDT) for emergency airway access. In a case series90 of nine patients who were in severe respiratory distress, in which intubation by conventional means had been unsuccessful, all nine patients were successfully intubated using the PDT technique. The average time to gain access to the airway in the authors’ institution with this technique is reportedly 2.8 min, if performed by an experienced provider.90 Whenever possible, ventilation should be provided while access to the airway is being established (e.g., LMA). While elective PDT in the critical care setting is safe and effective,91 more data are needed to establish its utility in emergency airway management.

Extubation of the Difficult Airway

Extubation of the patient with a known difficult airway requires some planning should respiratory failure and the need for reintubation arise. Besides routine extubation criteria, the cuff leak test has been advocated as a tool for predicting postextubation respiratory stridor. However, the data on the utility of this test appear equivocal. While some authors92,93 have suggested that the cuff leak test might be a useful index of clinically significant laryngotraechal narrowing, others94,95 have not been able to confirm this association. In a more recent study using real-time laryngeal ultrasonography, Ding et al96 were able to demonstrate a significant relationship between the air column width during cuff deflation and the development of postextubation stridor. These data have been confirmed by a second recent, prospective randomized trial97 in 128 medical and surgical ICU patients. In this study, a reduced cuff leak volume, defined as < 24% of tidal volume, was a reliable indicator for identifying patients with a high risk for developing stridor. Fur-
thermore, Jaber et al\textsuperscript{97} were able to show that in patients who are at risk (eg, traumatic intubation, prolonged intubation, or previous accidental intubation) a leak volume of < 130 mL or 12% of the tidal volume has a sensitivity of 85% and a specificity of 95% for the development of postextubation stridor.

Initially described by Benumof,\textsuperscript{98} extubating the patient via an airway exchange catheter (AEC) to retain a conduit for possible reintubation has been described by several authors.\textsuperscript{99,100} In a prospective study\textsuperscript{101} of 40 patients who had one or more risk factors for difficult reintubation, an AEC allowed for uncomplicated reintubation (n = 4) without desaturation on the first attempt. This was subsequently confirmed in a prospective, observational study\textsuperscript{102} in patients who had undergone maxillofacial and major neck surgery, and were considered to be impossible to reintubate by direct laryngoscopy. Reintubation was easily achieved with the AEC up to 18 h after extubation.\textsuperscript{102} An advantage of this strategy is the ability to insufflate oxygen through the catheter to avoid oxygen desaturation while assessing the patient for evidence of respiratory distress or compromise.

**Summary**

Managing the airway of a critically ill patient poses some unique challenges for the intensivist. The combination of a limited physiologic reserve in the patient and the potential for difficult mask ventilation and intubation mandates careful planning with a good working knowledge of alternative tools and strategies, should conventional attempts at securing the airway fail. If difficulty in managing a patient’s airway is anticipated, the use of awake fiberoptic techniques should be strongly considered. Although the use of muscle relaxants may facilitate endotracheal intubation, they must be used with extreme caution, and the clinician must have the requisite skills and alternative equipment to secure the airway if standard direct laryngoscopy and endotracheal intubation cannot be accomplished. Given the potentially high complication rate of endotracheal intubation in an ICU environment, future research should be directed at developing protocols to increase the safety of airway management in the ICU. Finally, providing adequate ventilation to the patient who is experiencing respiratory failure takes precedence over endotracheal intubation in order to avoid adverse outcomes related to profound hypoxemia.

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