Critical Airway Skills and Procedures

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KEYWORDS

• Airway • Airway adjuncts • Endotracheal intubation

KEY POINTS

- Airway management is a critical skill for emergency physicians.
- Careful airway assessment and preplanning are essential in determining which patients require invasive airway management and what equipment will be required to successfully manage the patients' airway.
- Airway management is a team-based procedure, and the emergency physician must be receptive and responsive to team input to maximize the safety of the procedure.

Airway management is a critical procedure and essential skill necessary for all physicians working in the emergency department. Optimal resuscitative treatment of medical and trauma patients often revolves around timely and effective airway interventions that can be challenging in the acute setting, especially in critical patients. Time-honored airway techniques and procedures combined with recent advances in rapid sequence intubation (RSI), video laryngoscopy, and further advanced airway techniques now offer emergency clinicians a wide range of exciting new options for improving this crucial component of acute care and management.

AIRWAY MANAGEMENT DECISION MAKING AND BASIC MANAGEMENT

Initial patient assessment forms the cornerstone of further advanced airway management, and the primary evaluation should focus on the quick identification of those who may need respiratory support. This evaluation includes assessment for the patency of

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the airway and adequacy of ventilatory effort, potential hypoxia, or presence of illness or injury that could result in further deterioration of the patients' respiratory status. These initial efforts should then guide proper management techniques and interventions to improve the patients' overall condition and optimize both oxygenation and ventilation.

In general, patients with airway management issues may be divided into those who need an immediate definitive intervention versus those who are more stable or less urgent. The first category is generally identified as a *crash airway* and must be managed without delay.[1] The second group may be assessed in a more systematic fashion in an effort to determine the next best step in treatment and to identify factors that could make airway management difficult.

Primary efforts should focus on airway patency, and any potential obstruction should be immediately treated. Simple airway repositioning may improve occlusion from the tongue and may include varied techniques, such as the jaw thrust or chin lift method. Inspection may also demonstrate airway occlusion from blood, vomit, or other foreign bodies that should be quickly removed. Patients with altered levels of consciousness may not protect their airway and may require insertion of an oropharyngeal airway or a nasopharyngeal airway in an effort to overcome posterior tongue displacement or loss of pharyngeal muscle tone.

In cases of potential respiratory compromise, it is also wise to identify early those patients who may have difficulty with airway management and include this as a component of the initial assessment. The commonly used mnemonic MOANS (**Table 1**) can help identify those who may be difficult to provide ventilatory support via a bag valve mask (BVM), and its individual components have been validated in multiple studies.[2–4] Similarly, the mnemonic LEMON (**Table 2**) may be used to identify potential difficulties with endotracheal (ET) intubation.[5,6]

The initial evaluation using pulse oximetry to identify hypoxia is now almost universal in prehospital and emergency triage vital signs and provides a useful initial screen for those with potential respiratory issues and complaints.[7] Pulse oximetry also gives useful feedback on the effects of supplemental oxygen and assessment of further treatment, delivering easily obtainable and noninvasive real-time information for providers. In more critical patients, continuous pulse oximetry is essential for the process of RSI and for further management of patients on noninvasive positive pressure ventilation or mechanical ventilation (MV). As with all technology, there are limitations, including factors like motion artifact and cardiac arrhythmias, and physical barriers, like nail polish that may cause false readings.[8,9] Pulse oximetry also provides

Table 1
MOANS: a mnemonic for identifying patients at risk for poor bag-valve-mask seal

MOANS[2]	Criteria
Mask seal	Beards, facial injury
Obesity/obstruction	BMI >26, airway obstruction, obstetric patients
Age	Aged older than 55 years
No teeth	
Stiffness	Increased airway resistance (asthma, COPD), stiff lungs (pulmonary edema, CHF, pneumonia)

Abbreviations: BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.

Table 2
LEMON: a mnemonic for identifying patients at risk for difficult endotracheal intubation

LEMON[4]	Criteria
Look	A quick external examination of the patient for potential signs of airway management problems.
Evaluate the 3-3-2 Rule	Examine the airway for structural and anatomic factors that may make intubation difficult. Normal findings should show a mouth opening that accommodates 3 of the patient's fingers, a mandible measuring 3 fingers from the mentum to the hyoid bone, and a distance of 2 fingers from the hyoid bone to the thyroid notch. When present, these factors predict sufficient spatial relationships between the mouth, the mandible, temporamandibular joint mobility, and the larynx to allow for successful direct laryngoscopy and eventual endotracheal intubation.
Mallampati Score	Assessment of the posterior oropharyngeal structures visualized when the mouth is open and the tongue is fully protruded.
Obstruction	Upper airway obstruction from foreign bodies, edema, stridor, or soft tissue masses.
Neck Mobility	Assessment of difficulty of potential neck positioning to assure optimum angles for visualization of the glottis. Examples include potential cervical spine injuries, rheumatoid arthritis, or degenerative arthritis.

information solely on oxygenation and gives no information on ventilatory status, carbon dioxide levels, or acid base status.[7]

An additional useful noninvasive measurement of respiratory status and ventilation is the use of capnography. This technology measures the partial pressure of carbon dioxide (CO_2) during ventilation and provides a useful proxy measurement of arterial CO_2. This measurement may occur as a one-time measurement, as in the use of a colorimetric end-tidal CO_2 detector, or as an ongoing measurement of exhaled CO_2 displayed as a continuous capnogram. At present, these measurements are most useful in confirming and assessing ET tube placement, for procedural sedation, and for monitoring patients with obstructive lung disease, like chronic obstructive pulmonary disease (COPD) or asthma, that may result in CO_2 retention and potential subsequent acidosis.[10]

Patients who are found to have inadequate ventilation may require assistance with a BVM to deliver positive pressure ventilation in addition to supplemental oxygen. This technique relies on an experienced operator who can ensure a tight mask seal and works well in conjunction with an oropharyngeal or nasopharyngeal device (**Fig. 1**). During the initial evaluation, patients who may be difficult candidates for adequate BVM should be identified by the use of the mnemonic MOANS, as described earlier, or by the identification of any factor that may make the seal of the mask inadequate. The major drawbacks to BVM revolve around issues of lack of protection from pulmonary aspiration and gastric inflation, both of which may occur with increased airway pressures necessary for adequate ventilation.

BRIDGING ADJUNCTS

Although advanced airway procedures are often required to manage patients with impending respiratory failure, there are a few alternatives to consider before

Fig. 1. Correct hand placement and technique for bag-valve mask ventilation.

proceeding to ET intubation or other invasive airway interventions. ET intubation is not without risk. Commonly reported adverse events surrounding intubation include trauma to the upper airway structures, ET tube–induced tissue necrosis, loss of protective anatomic barriers to infection and the resulting nosocomial pneumonias, patient discomfort and agitation, as well as increased intensive care use and associated costs.[11–13]

Noninvasive ventilation (NIV) is delivered via positive pressure applied through either a face mask or nose mask to spontaneously breathing patients. For optimal use, patients must have sufficient respiratory effort to be able to effectively use the device. NIV has been acknowledged as a viable airway management strategy since biblical times when bellows and other positive pressure devices were used to maintain respiration during resuscitation.[14] In more modern times, NIV was used during the polio epidemics of the 1950s to sustain the ventilation of patients with polio using devices, such as the chest shell and the iron lung.[15] In today's emergency department, 2 noninvasive adjuncts should be at the fingertips of an emergency physician: continuous positive airway pressure (CPAP) and bilevel positive airway pressure (BiPAP).

CPAP is a critical airway procedure that requires patients to breathe against a continuous and constant positive pressure that is delivered through a tight-fitting face mask. Breathing against a continuous positive pressure encourages the recruitment on atelectatic lungs, reduces the work of breathing, improves pulmonary compliance, and may decrease the need for intubation.[16] The typical settings are 10.0 to 12.5 cm H_2O.

BiPAP ventilation cycles between 2 modes of positive airway pressure. During inspiration, BiPAP ventilation provides high-flow inspiratory positive airway pressure. Sensing the patient's native flow rate, the BiPAP ventilator responds with high-flow pressure for either a fixed time period or until the gas flow rate decreases less than a preset threshold, usually 25% of the expiratory volume. At the conclusion of inspiration, the device switches to the expiratory positive airway pressure, delivering a lower positive pressure to splint open alveoli and to maintain a fixed alveolar pressure. Common starting settings are 10 cm of inspiratory pressure and 5 cm of expiratory pressure.

Five conditions warrant consideration of noninvasive ventilation, and only 3 of which apply directly to the emergency department setting.[17] The use of NIV in COPD is strongly supported by the medical literature.[18–22] Both CPAP and BiPAP have demonstrated decreased intubation rates for patients with acute cardiogenic pulmonary edema and should be considered the first-line therapy for appropriate patients (**Table 3**).[23–27] An emerging use of NIV, which is not typically considered in the

Table 3
Indications and contraindications of use of NIV

Indications	Contraindications
Alert and cooperative patient	Decreased mental status (GCS <10)
Severe dyspnea at rest	Uncooperative patient
Use of accessory muscles of respiration	Poor respiratory effort
Respiratory rates >30 bpm	Aspiration risk
Hypercarbic respiratory failure	Inability to clear secretions
Acute respiratory acidosis (pH <7.30)	Hemodynamic instability
	Face trauma, surgery, or deformity
	Upper gastrointestinal bleeding
	Cardiac or respiratory arrest

Abbreviation: GCS, Glasgow Coma Scale.

emergency setting, is the application of NIV for patients who are immunocompromised.[28,29] ET intubation and MV are associated with significant morbidity, particularly nosocomial pneumonias. Avoidance of ET intubation in this patient population may come with resulting decreases in mortality and intensive care length of stays.[28] NIV ventilation may also be particularly useful for patients with hematological malignancies, patients who have elected a do-not-intubate status, and for relief of severe dyspnea in patients with cancer.[29] Nonemergency department indications include the use of NIV in extubation failure among patients with COPD and use in postoperative patients.[30–33] Although promising, controversy exists regarding the use of NIV in patients with asthma.[34,35]

Two hours is considered an adequate trial if NIV is to be implemented.[36,37] Improvements in acidosis and carbon dioxide retention should be demonstrated within this time window. Failure to demonstrate improvement should lead the clinician to proceed to intubation and MV. Of course, any worsening of these parameters during the trial should prompt the clinician to more aggressively manage the patients' ventilation. Other criteria for failed NIV trial are worsening mental status or agitation, worsening oxygenation, hemodynamic instability, or inability to tolerate the mask.[7] There are few complications associated with use of NIV. The most common complication is skin breakdown or necrosis secondary to the tight-fitting masks. Some patients may experience retention of secretions or gastric distention. Others may find the mask itself intolerable and the NIV trial may fail because of patient anxiety or inability to tolerate the tight-fitting mask.

ET INTUBATION

ET intubation is a key procedure for emergency physicians and is taught in every emergency medicine residency in the United States. Often, clinicians are quick to jump to ET intubation in patients who might be better managed using skills we have already discussed, such as simple airway positioning maneuvers; nasal or oral airways; or bridging adjuncts, such as BiPAP. The physical skill of ET intubation is relatively easy to master with enough practice, but applying the appropriate assessment skills and knowledge to know when to intubate is often very complex.

Indications

Indications for ET intubation fall into 2 categories: reflexive and relative. The most obvious reflexive indication is for those patients who are not breathing. Patients with severe facial injuries or those who are so obtunded that they can no longer protect their airway also require ET intubation. It has been traditionally taught that the absence of a gag reflex signals the need to intubate; however, Davies and colleagues[38] demonstrated that approximately 37% of the general population have an absent gag reflex. It may be more prudent to assess patients' ability to swallow spontaneously and handle their secretions. These reflexive indications require rapid patient assessment and intervention to prevent fatal outcomes.

Relative indications allow the emergency clinician a bit more time to prepare and assess patients using the assessment techniques, such as LEMON, mentioned earlier in the article. Patients failing bridging adjuncts, such as BiPAP, or those who present in extremis from COPD, asthma, or other respiratory emergency will also ultimately require intubation. In addition, patients with a clinical condition, such as facial trauma, abscess, or burns, may also require intubation as a more elective procedure should their condition suggest eventual deterioration and airway compromise.

Preplanning

In an airway emergency, the only critical failure is a failure to ventilate. Failing to successfully intubate patients is not a critical failure. Beginning with the end in mind will improve airway management success rates and will improve patient outcomes. Inability to ventilate patients is a true emergency and requires the emergency clinician to move rapidly to place an ET tube or proceed to surgical airway.

Perhaps the most important airway procedure occurs months in advance of the particular need to intubate an individual. Preplanning for airway emergencies will make the emergency intubation not only more efficient and successful but also safer for patients. Emergency physician practice groups should consider either developing or adopting an emergency airway checklist. Evidence from our intensive care and anesthesia colleagues has demonstrated the utility of checklists in decreasing complications and adverse outcomes.[39–42] Emergency physicians should plan well in advance for airway emergencies by assembling all essential airway equipment and supplies, including rescue devices and surgical equipment, in an airway cart or similar depot that can be easily moved to the patients' bedside; this should be a standard emergency department policy. While the airway cart is being moved to the patients' bedside, the clinician should assess the patients' anatomy and airway while keeping in mind which rescue devices might be most appropriate should intubation prove difficult. Patients should be preoxygenated, and the intubator should conduct a brief time-out to ensure that every team member understands their role in the procedure and that all the required equipment, personnel, and supplies are in the room.

Equipment

The required equipment for ET intubation is listed in **Table 4**. It should be standard practice to monitor patients with a cardiac monitor, pulse oximetry, blood pressure measurements, and capnography. All of these are essential to adequately evaluate patients during an airway emergency.

The BVM device should come with a variety of facial mask sizes to accommodate large adults as well as children. Suction must be available at the bedside with an attached yankauer suction tip. Oropharyngeal or nasopharyngeal airways will improve the ability of the person bagging the patients to ventilate the patients and should always be available within short reach.[43] Oropharyngeal airways are measured from the corner of the mouth to the angle of the jaw. They should only be used in unresponsive patients with an absent gag reflex so as not to stimulate vomiting and subsequently increase the risk of aspiration.[43] Nasopharyngeal airways are measured

Table 4
Equipment for ET intubation

ET Intubation Equipment	Backup Devices
BVM	Bougie
Suction	Laryngeal mask airway
Airways (oropharyngeal and nasopharyngeal)	King airway
ET tubes of appropriate sizes	Flexible fiberoptic endoscope
Stylet	Cricothyroidotomy
Laryngoscope	
Laryngoscope blades (both curved and straight)	
Magill forceps	
10-mL syringe	
Stethoscope	

from the nares to the tragus of the ear and are inserted using a lubricant into the nares at an angle perpendicular to the face.[43] These devices should not be used in patients with facial trauma or basilar skull fractures and should be used with caution in anticoagulated patients or those with nasal deformities.[43]

ET tubes are usually made of polyvinyl chloride and are available in a variety of sizes (2.0–10.5 mm of internal diameter) (**Fig. 2**). For most adults, ET tubes between 7.5 mm and 8.5 mm will provide an acceptable first pass rate as well as an adequate ventilation capacity.[44] It is useful to have a full range of sizes readily at hand to accommodate unexpected airway sizes. For children, the Broselow Pediatric Emergency Tape (Armstrong Medical Industries, Lincolnshire, IL, USA)[45] will provide guidance for the appropriate ET tube size based on patient size. Adult tubes are usually cuffed, whereas pediatric tubes come in both cuffed and uncuffed varieties. An intubating stylet is a useful aid, which lends rigidity to the ET tube and provides the intubator with the ability to form the stylet and ET tube to the patients' specific anatomy (see **Fig. 2**). Although many advocate a stylet as an adjunct for difficult airways, it may be a useful tool in every intubation.

The laryngoscope is simply a viewing device to bring the airway anatomy into view under lighted conditions to facilitate the correct placement of the ET tube. The traditional laryngoscope is a left-handed instrument consisting of a handle housing

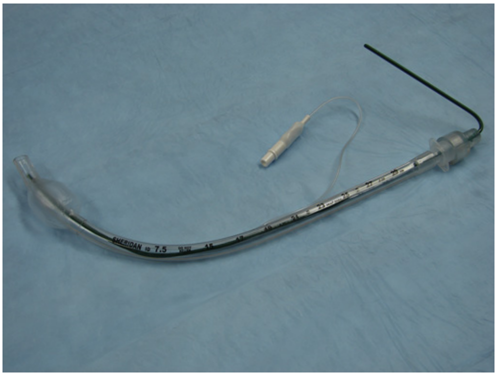

Fig. 2. Endotracheal tube with stylet in place.

batteries that power a light on the end of a blade inserted into the handle. More recently, emergency physicians have begun to use video laryngoscopes that use a digital video camera that projects the airway anatomy onto a video monitor (**Fig. 3**). This device allows the intubator a larger image of the airway and facilitates both increased first pass success rates and decreased intubation time.[46] The lighted blade attached to the laryngoscope handle comes essentially in 2 varieties: curved and straight (**Fig. 4**). Each variety is available in sizes ranging from 0 for infants to 4 for large adults. There are many blades on the market, each differing slightly in construction with a flange here and an extra ridge there, but essentially it all boils down to intubator preference and the specific anatomy of the patient being intubated. Emergency physicians may have a preference for curved versus straight blades but should be facile with both types.

Other standard equipment for intubation should include Magill forceps,[47] which may be useful in guiding the ET tube into the larynx when an anterior airway is encountered, as well as a 10-mL syringe to inflate the cuff once the ET tube is placed successfully and a stethoscope as one adjunct to confirm tube placement.

Technique

The technical aspects of intubation are simple to write but hard to perform without focused mentored practice. Intubation is a core skill acquired in an emergency medicine residency, but it is not enough to learn the skill during residency because skills deteriorate without practice.[48] Most emergency physicians intubate frequently enough to maintain skills, but difficult airway algorithms and skills are more difficult to retain because these instances occur so infrequently. Many are currently advocating the use of simulators for skill practice and retention; but community emergency

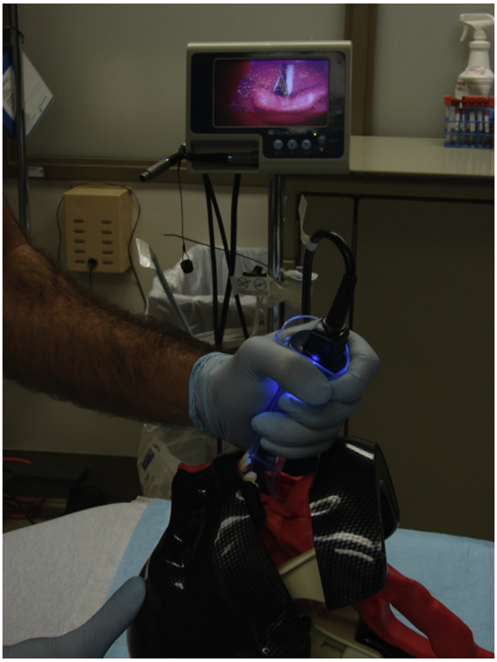

Fig. 3. Video laryngoscopy demonstrating visualization of the vocal cords in a manequin model.

Fig. 4. Laryngoscope handle and two blades.

physicians may not have access to simulators, which are more commonly located in large academic medical centers.[49,50] Other options for skill retention include operating room skill performance through collegial relationships with anesthesia or mannequin practice. It is incumbent on the emergency physician to maintain skill performance.

Once the emergency physician has conducted a brief time-out to ensure that every team member understands their role in the procedure; that all the required equipment, personnel, and supplies are in the room; and that the equipment is functional, the next step should be to position the patient. Taking time to properly position the patient can spell the difference between success and failure. The stretcher should be at about the height of the intubator's midchest.[51] Except in the setting of suspected cervical spine injury, the patient should be placed into a sniffing position. The sniffing position allows for an optimal view of the glottic opening by aligning the oral, pharyngeal, and laryngeal axes.[52] This position may be accomplished be flexing the neck and extending the head. Recent evidence suggests that simply extending the head as a single maneuver may be as effective as the combined maneuver of neck flexion and head extension.[53] Suspected cervical spine injury mandates immobilization of the neck, thus, preventing the intubator from using the sniffing position and care must be taken to assign a team member to maintain cervical spine immobilization during the procedure. The patient should be preoxygenated with 100% O_2 using a non-rebreather mask if the patient has an adequate ventilatory effort or using the BVM technique if there is inadequate effort. During the procedure, a team member should be appointed to apply the Sellick maneuver. Consisting of firm pressure over the thyroid cartilage, the intended outcome of the maneuver is primarily to minimize the risk of gastric aspiration. The maneuver should be initiated at the beginning of positive pressure ventilation and continued until the ET tube cuff is inflated in the trachea. Some have questioned this maneuver's effectiveness, but it remains a recommended part of the intubation process.[54]

From this point forward, it is assumed that the patient is awake and spontaneously breathing. For those patients who are not breathing, the sedation and paralytic steps can be skipped as part of a *crash airway* algorithm. The patient should be properly sedated before proceeding. Once sedated, the patient's mouth is opened using a scissoring motion with a crossed right forefinger and thumb. The forefinger is placed on the patient's upper teeth and the thumb on the lower teeth to use a scissoring motion to open the mouth. After assuring adequate preoxygenation and the ability to ventilate the patient using the BVM technique, the patient may be chemically paralyzed using RSI techniques detailed later in this article.

The laryngoscope handle is held in the intubator's left hand, and the blade is inserted into the right side of the mouth to sweep the tongue into the left side of the mouth. The laryngoscope is then advanced into the airway slowly taking note of the airway anatomy with a goal of visualizing the epiglottis (**Fig. 5**).[52] If a curved blade is being used, then the blade is placed into the vallecula and forward pressure is applied to lift the epiglottis and bring the vocal cords into view.[52] If a straight blade is being used, the blade is placed beneath the epiglottis.[52] Using an upward and slightly forward motion, the vocal cords are brought into view. Care must be taken to never use the teeth as leverage. Once the vocal cords are visualized, the ET tube is taken in the right hand and advanced into the airway until the cuff passes through the cords. The laryngoscope can now be removed from the mouth and the stylet removed from the ET tube. ET intubation attempts should be limited to no longer than 30 seconds, although shorter limits may be required based on patient oxygen saturation and heart rate.[55] If the intubator is unable to place the tube within the time limit, then the attempt should be aborted, the patient ventilated, and preparations made for another attempt.

A failed attempt at intubation provides an opportunity to remediate or correct problems in positioning, equipment, or procedure. The intubator may want to consider placing a rolled towel beneath the patient's shoulder to optimize positioning.[52] A change in laryngoscope blade may be warranted or suction may be required. The BURP maneuver may also be a useful addition to the procedure: firm backward (B), upward (U), rightward (R) pressure (P) is applied to the patient's thyroid cartilage to bring the vocal cords into better view.[56,57] Although some have questioned the utility of this maneuver, it may be a useful adjunctive maneuver in a difficult intubation situation.[58]

Even when done correctly by the most skilled clinician, intubation can occasionally have complications.[59] These complications include airway trauma, such as dental

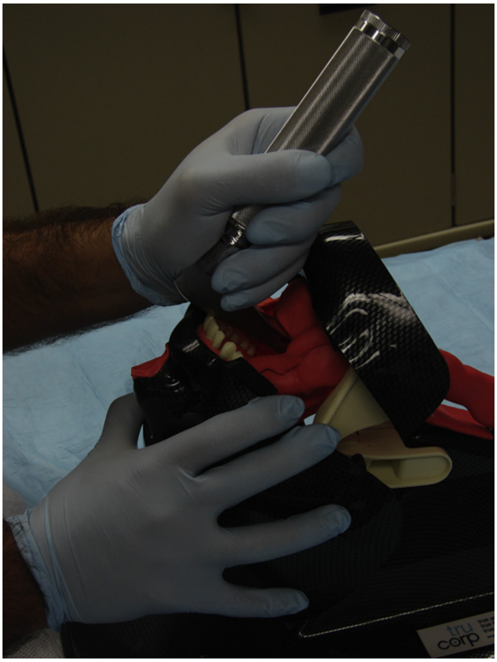

Fig. 5. Correct technique for laryngoscopy in a mannequin model.

injury and bruising or laceration of the lip, tongue, or mucosa. Many patients complain of sore throat after intubation. Other reported complications of emergency intubation are glottic injury, aspiration, retropharyngeal bruising, or rarely perforation.[60]

Postintubation Procedures

Once the ET tube has been placed through the vocal cords, the cuff should be inflated with 10 cm^3 of air. After tube confirmation is assured, the cuff inflation pressure should be measured and the least amount of air necessary to create a seal during ventilation should be used. There are many methods for confirming tube placement; but unfortunately no one method has proven to be 100% reliable, and relying on any single confirmation method is suboptimal.[61,62] Suggested methods are noted in **Box 1**. Li[61] published a meta-analysis of capnographic clinical trials in 2001. Using a sample of 2192 intubations, he reported a 93% sensitivity (95% confidence interval [CI] 92%–94%) and a 97% specificity (CI 93%–99%) for ET tube placement confirmation using capnography. He also reported the false-negative failure rate (tube in trachea but capnography reports esophagus) to be 7% and the false-positive rate (tube in esophagus but capnography reports trachea) to be 3%. Most usefully, he translates this information into a number needed to harm using capnography as a sole confirmation procedure. For every 10 patients in whom ET intubation is confirmed with capnography alone, one will be harmed (number needed to harm: 14 for false negative, 33 for false positive, and 10 for both).[61] Although waveform capnography is not perfect, it is the best among the recommended confirmation methods.[63] There is evidence, though, that waveform capnography is not widely available in emergency departments in the United States.[64]

Recently, several studies have examined the usefulness of ultrasonography to evaluate the placement of an ET tube.[65–68] Ultrasound can be used in 2 different ways to confirm placement. First, the application of the transducer to the neck can visualize the placement of the tube during the procedure of intubation. Secondly, using the sliding lung sign during bag ventilation, ET tube placement can be confirmed.

BACKUP DEVICES

Not every intubation procedure goes as planned, and emergency physicians must always have a backup plan in mind. During the initial assessment of the patient's

Box 1
Methods of ET tube placement confirmation

- Waveform capnography
- Colorimetric end-tidal carbon dioxide detector
- Auscultation of breath sounds
- Ultrasonography
- Direct visualization of the tube between the cords
- Self-inflating esophageal bulb
- Fogging of the ET tube
- Rise and fall of the chest
- Pulse oximetry readings
- Improvement in the patients' condition (color, heart rate)

airway anatomy, the emergency physician should have made some decisions about which backup devices might be most appropriate for that specific patient. Once it is clear that the intubation procedure is difficult, the emergency physician should move quickly to a backup device or procedure.

The bougie is an intubation aid that many clinicians find useful in patients with anterior airway anatomy or poor visualization of the vocal cords such as occurs in trauma patients with cervical spine immobilization.[69,70] The bougie is a semirigid, straight rod with a hockey-stick bend at one end and can be inserted into the airway to locate the trachea and then to serve as an introducer over which the ET tube can be placed. Typically, the bougie is used under direct laryngoscopy but may be used to facilitate nasotracheal intubation,[71,72] retrograde intubation,[73] or cricothyrotomy.[74]

The bougie is inserted into the airway under direct visualization using a laryngoscope. Passing the bougie tip beneath the epiglottis and into the trachea, vibrations or clicks are palpated through the bougie shaft as the tip of the bougie passes against the rigid tracheal rings. The inability to advance the bougie past 40 cm in an adult also indicatives tracheal placement because the bougie will be stopped at the carina or by the small lumen of the bronchus.[75] If it was in the esophagus, there would be no impediment to its advancement. Kidd and colleagues[76] studied the reliability of these two signs for predicting placement of the bougie in the trachea. They reported 89.7% accuracy for tracheal clicks and 100% accuracy for "tracheal hold up." Once tracheal placement is confirmed, the ET tube can be advanced over the bougie. Advancement past the vocal cords can occasionally require gentle pressure and 90°counterclockwise tube rotation.[77]

Extraglottic devices can also provide the clinician with an airway alternative allowing for oxygenation and ventilation without the requirement to thread an ET tube through the vocal cords. Useful in both difficult and failed airways, extraglottic devices are commonly used in the operating room, the emergency department, and in prehospital environments. There are many such devices on the market but this discussion is confined to the most common devices: the Laryngeal Mask Airway (LMA International N.V. Willemstad, Curacao), the Combitube (Kendall-Sheridan, Mansfield, MA, USA), and the King Airway (King Systems, Noblesville, IN, USA).

The LMA is a large-bore stem with a flexible cuffed mask on the end designed to fit over the tracheal inlet (**Fig. 6**). It is a blind insertion device often used in anesthesia when ET intubation is unnecessary or in emergency situations when intubation fails.[78] Once inserted and seated, the cuff is inflated to create a low-pressure seal around the

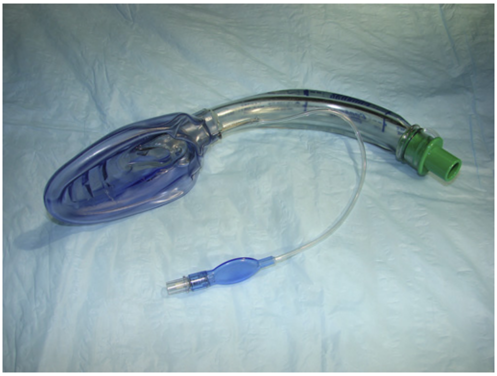

Fig. 6. Laryngeal mask airway.

tracheal inlet. Several investigators report the utility of this device in the hands of less experienced clinicians as a first-line device as well as a rescue device for failed airways in any setting.[79–81]

The LMA is available in a variety of adult and pediatric sizes as well as several different models with differing functions. Notably, an intubating version of the LMA (I-LMA. Laryngeal Mask Airway. LMA International N.V. Willemstad, Curacao) exists and allows for the passage of an ET tube through the mask and into the trachea. The I-LMA is placed blindly using a metal handle, and an enlarged stem lumen allows for the passage of an ET tube through the stem and into the trachea through the mask. The I-LMA uses a proprietary nonkinking ET tube. Many investigators report up to a 95% success rate for intubation of the trachea using an I-LMA.[82–88] It should be noted that none of the LMA devices protect the trachea from aspiration in patients with full stomachs or copious secretions. Some investigators advocate the use of the bougie through an LMA as a tracheal placeholder and then passage of an ET tube over the bougie.[89]

The Combitube device has been used extensively in the prehospital environment as a rescue device with success rates of up to 93%.[90] The Combitube is a blind insertion, dual-lumen airway designed to be placed in the esophagus but can also be used when inserted into the trachea. The Combitube has a large cuff that, when correctly positioned, will lie in the posterior pharynx above the glottis. The distal end of the tube has a smaller cuff that, when placed in the esophagus, occludes that passage to force air into the tracheal inlet. The Combitube is gradually losing favor to the newer and easier-to-use King Airway.[91]

The King Laryngeal Tube (LT) Airway (King Systems, Noblesville, IN, USA) is a blind insertion, single-lumen tube that is shorter, easier to manipulate, and easier to position than the Combitube (**Fig. 7**). Additionally, it only has a single cuff inflation port, which inflates both cuffs at the same time. When properly positioned, the proximal cuff seals the hypopharynx and the distal cuff seals the esophagus, allowing for ventilation through the port positioned between the cuffs and at the laryngeal inlet. Russi and colleagues[92] demonstrated the ease and speed with which a King LT can be placed in a difficult airway simulator, whereas Guyette and colleagues[93] have demonstrated its successful use in the actual rescue of difficult and failed intubations. The King LT ventilating tube is large enough to allow for the passage of a flexible endoscope, a tracheal tube introducer, or a bougie. The use of these adjunct devices, along with the King LT, may allow for the subsequent passage of an ET tube, although complications, such as perforation of the trachea, have been reported.[94–96]

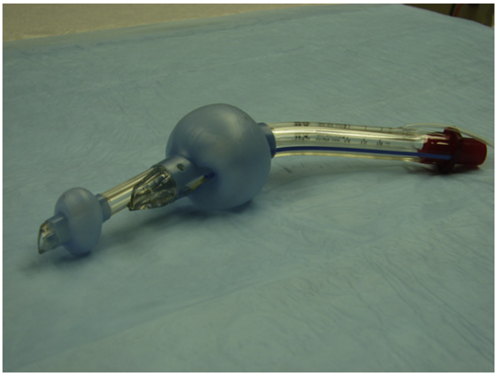

Fig. 7. King airway.

BACKUP PROCEDURES

In addition to backup devices, the emergency physician must also be facile with backup procedures. Two alternative airway procedures are discussed: nasal intubation and flexible fiberoptic intubation. Cricothyrotomy is discussed in the next section.

Nasal intubation can be performed for a variety of reasons and in a variety of situations. For example, it may be preferred as an awake intubation technique along with fiberoptic visualization in the setting of oral airway obstruction, such as severe lingual edema or trauma.[97,98] Nasal intubation may also be used in the setting of breathing patients in whom oral intubation has failed. Three techniques are possible in accomplishing nasal intubation. In the blind insertion technique, the lubricated ET tube is introduced into a nare and advanced over the floor of the nasopharynx into the hypopharynx while the intubator listens at the tube end for breath sounds. As the patient inhales, the tube is advanced in the direction of air movement into the laryngeal inlet and through the vocal cords. Devices, such as directional tipped ET tubes or the Beck airway airflow monitor may increase success rates in blind nasal intubation attempts.[99] Alternatively, in situations when nasal intubation can be accomplished using direct laryngoscopy, the ET tube is advanced along that nasal floor through the nasal pharynx until visualized in the posterior pharynx and then guided through the vocal cords under direct visualization. Severe midface trauma is a relative contraindication for nasal intubation.[100,101]

Fiberoptic intubation allows for indirect visualization of the laryngeal inlet and vocal cords to facilitate the correct placement of the ET tube via either an oral or nasal route.[102] Using a flexible fiberoptic endoscope over which an ET tube has been threaded, the intubator directs the flexible endoscope into the hypopharynx visualizing landmarks and anatomy as the tube progresses. The tube is passed through the vocal cords, and the ET tube is threaded off of the bronchoscope and into position in the trachea.[102] Preparation for fiberoptic intubation requires time and patient cooperation. Patients should be awake, breathing spontaneously, and adequately oxygenated. The technique requires physician experience and practice with the device well in advance of the immediate need to intubate. Additionally, the device and associated equipment is expensive and not maintained in many emergency departments.

Fiberoptic intubation is particularly useful for patients in whom the initial airway assessment has suggested a difficult airway and in whom chemical paralysis would be dangerous.[102] Examples of patients for whom fiberoptic intubation could be considered include those with limited mouth opening, facial trauma, lingual edema or trauma, oral obstructions from infection or tumor, or unusual upper airway anatomy (whether congenital or postsurgical).[102] Contraindications include rapid airway compromise; extensive secretions, such as emesis or bleeding; hypoventilation; or poor patient cooperation.[102]

RSI

RSI is often chosen in emergency settings because it rapidly induces unconsciousness and chemical paralysis of previously awake and breathing patients in a controlled manner. It is critical to remember that emergency patients have often not fasted and are at much higher risk of aspiration of secretions or emesis.[103] A decision to use RSI also requires that the emergency physician has made a thorough assessment of the patient's airway and has planned for the difficult airway scenario.

RSI requires a sequential series of steps to be safely and efficiently completed.[104] The first step is preparation. The emergency physician must prepare 3 elements: the equipment, the patient, and the team. The authors have previously discussed appropriate intubation equipment to have at the bedside and readily available. This equipment should include backup devices and equipment. Patients should be informed and preferably consented to the procedure if time and circumstances allow. Patients should also be preoxygenated with high-flow oxygen through a non-rebreather mask for up to 5 minutes before proceeding. Emergency airway management and the patients' condition may not allow for this ideal preoxygenation interval. Preoxygenation allows for supersaturation of the alveoli through nitrogen washout. Baraka and colleagues[105] have demonstrated that 3 minutes of tidal volume breathing is sufficient to preoxygenate patients. In ideal models, investigators suggest that preoxygenation can buy the clinician about 8 minutes before the oxygen saturation levels drop less than 90%; however, both Famery and Mort have shown that this ideal desaturation curve is not reliable or valid in the critically ill patients that most emergency physicians will be intubating using RSI.[106–108] The final preparatory element is the team. RSI requires a team of personnel, each of whom understands their role in the event and each of whom is alert to possible safety concerns or possible human error.[109] The team leader should ensure that team members know each other, that they understand their role, and that they acknowledge the need to speak up when they are concerned about the evolution of the procedure.

Once the preparatory phase is complete, the second step is medication, which has 2 phases. The emergency physician may consider pretreatment with medications, such as lidocaine, an analgesic, atropine, and a defasciculating agent, although the evidence for these pretreatments is unconvincing and conflicting. Typically administered 2 to 3 minutes before induction and paralysis, these medications are proposed as blunting the physiologic response to intubation. It has been suggested that lidocaine (1.5 mg/kg intravenously) as a pretreatment medication may blunt the increases in intracranial pressure, heart rate, and mean arterial pressure during intubation. These findings have not been consistently demonstrated; although it is advocated for use in patients with head injuries or bleeding or intracranial tumors, its use is left to the judgment of the clinician.[110–112] Analgesic administration also carries no convincing evidence to suggest routine use as a pretreatment.[113,114] Although atropine may decrease the incidence of bradydysrhythmias in children during intubation, these dysrhythmias are usually self-limited and of little consequence. Atropine should at least be available during the intubation of young children.[115,116] Defasciculating doses on nondepolarizing agents may decrease the intensity and duration of muscle fasciculation after the administration of succinylcholine.

Induction agents should be administered after pretreatment medication (if any). Producing a rapid loss of consciousness, induction medications allow for control of patients and prevent psychological harm during the administration of paralytic agents. One of 4 induction agents is typically used in the emergency department: etomidate, propofol, ketamine, or midazolam.

Etomidate is one of the most commonly used agents in the United States for RSI induction.[117] This anesthetic agent has a short half-life and rapid onset of action. Additionally, it is very useful in patients with hemodynamic instability because it is less likely than other agents to cause decreases in blood pressure and very useful in patients with suspected head injury because it reportedly decreases intracranial pressure while maintaining normal arterial pressure.[118–120] Propofol also has a rapid onset of action, short duration, and is cerebroprotective; however, it is not useful in patients with hemodynamic instability because of its myocardial depressive profile.

Ketamine has regained popularity in the adult emergency department for use in RSI.[121] An N-methyl-d-aspartate receptor antagonist, ketamine carries both analgesic properties and the ability to create a dissociative state in patients. Once thought to cause increases in intracranial pressure, new research suggests that ketamine may improve cerebral perfusion and may have neuroprotective properties.[122–125] Midazolam is a benzodiazepine with relatively slower onset of action and longer duration of action that limits its effectiveness in RSI.[118] Additionally, midazolam often causes hypotension, making it not useful in the setting of hemodynamic instability.[118]

The final phase of the medication step is the administration of paralytics. The purpose of paralytic agents is to obliterate the patient's protective reflexes to facilitate efficient placement of the ET tube. It is important to remember that paralytic agents only paralyze; they do not provide sedation, amnesia, or analgesia and the clinician must remember to maintain adequate levels of appropriate medications to also meet these important needs. The clinician must choose between depolarizing agents, such as succinylcholine, and nondepolarizing agents, such as rocuronium, for paralysis. Succinylcholine has a very rapid onset requiring the clinician to be ready to manage the patient's airway as soon as the medication is delivered and a short duration of action. Succinylcholine is associated with the release of intracellular potassium and should be used with caution in patients who are known or suspected to be hyperkalemic.[126] Nondepolarizing agents, such as rocuronium, have both longer onset and duration of action. Potassium release is not associated with nondepolarizing agents, making these drugs useful in patients who are hyperkalemic; however, the use of nondepolarizing agents in patients with suspected difficult airways is not recommended to avoid the *cannot ventilate, cannot intubate* scenario. Having now completed the preparation phase and the medication phase, the final phase is the actual procedure of intubation. The procedure itself is no different from that described previously.

DIFFICULT AIRWAYS

One of the most important decisions an emergency physician can make when managing an airway is identifying a difficult airway. A difficult airway exists in patients when basic facemask ventilation is problematic or tracheal intubation is difficult. When a physician finds himself or herself in such a situation, this should immediately prompt the use of a difficult airway algorithm that includes the use of difficult airway adjuncts.[2,5,127] One should have experience with one or all of the following adjuncts before a difficult airway were to present itself.

In addition to the difficult airway adjuncts that have been mentioned previously, the lighted stylet presents a viable option in the setting of excessive secretions, blood, or trismus. The lighted stylet requires transillumination of the anterior neck and can be hindered by obesity or excessive ambient light.[128] One should consider dimming the lights when using this technique. The lighted stylet is a semirigid stylet with a light on the end and an ET tube preloaded on the stylet.[129] With the patient in the sniffing position, the lighted stylet is advanced blindly into the posterior pharynx. While advancing, one should look for evidence of a single light shining through the skin. On reaching the trachea, a distinct light will shine through the thin tracheal membranes and skin. Once visualized in this manner, the ET tube can be advanced and verified using standard technique. Visualizing a diffuse glow as opposed to a distinct point of light can identify an esophageal intubation.

The fiberoptic stylet (FOS) is another difficult airway adjunct.[130] The FOS is extremely useful in anterior airways and significantly cheaper than a video laryngoscope. However, if there is an abundance of secretions or blood, visualization is limited, making intubation that much more difficult. The FOS contains a fiberoptic device at the distal end of the stylet, allowing the physician to obtain a direct view of the posterior pharynx. Like the lighted stylet, the FOS is placed blindly into the posterior pharynx with the ET tube preloaded; but unlike the lighted stylet, the FOS can be advanced toward the trachea with direct visualization seen through an eyepiece at the proximal end of the stylet. Once the vocal cords are visualized, the stylet is advanced into the trachea and, subsequently, so too is the ET tube. Confirmation is obtained using the standard technique.

Another adjunct often forgotten is the retrograde wire intubation (RWI).[131] Because 2 operators are often required (one at the neck and one at the mouth), it is invasive, and can be complicated by upper airway obstruction or poor direct visualization, RWI is typically the very last option in rescuing a difficult airway. However, RWI can be rapidly attempted before a surgical airway is decided on and has less morbidity than a surgical airway.[131]

The neck should be prepped with povidone-iodine followed by the identification of the cricothyroid membrane. Subsequently, an 18-gauge needle should be placed through the cricothyroid membrane with immediate aspiration of air, thus, confirming placement of the needle in the airway. Once the needle is repositioned cephalad, a guidewire can be advanced through the needle. As the guidewire is advanced far enough into the oropharynx, one can use a McGill or alligator forceps to firmly grasp the distal tip of the wire. Immediately extract the wire out of the mouth. Once secured, the ET tube can be advanced over the wire using a Seldingerlike technique.[131] Placement can then be confirmed using the standard measures.

FAILED AIRWAYS

When intubation has failed and oxygenation cannot be adequately obtained a *failed airway* has occurred. The 2 traditional approaches, surgical open cricothyroidotomy and needle cricothyroidotomy, are the 2 solutions for a failed airway. When anticipating a failed airway, the LMA, Combitube, and King Airway previously mentioned may provide oxygenation while preparing for a surgical airway. Nonetheless, when a clinician is forced down this path, preparation is the key and includes a firm understanding of the involved anatomy as well as the complications of each technique.

The cricothyroid membrane is easily palpated between the thyroid and cricoid cartilages.[132,133] However, in patients with abnormal anatomy, the cricothyroid membrane can be found approximately one-third of the distance midline from the manubrium to the chin. The thyroid cartilage is the largest cartilage on the neck and often referred to as the *Adam's apple*.[134] The beginning of the cricothyroid membrane is inferior to the thyroid cartilage. Vasculature includes the cricothyroid artery and vein located at the superior border of the cricothyroid membrane and the inferior portion of the thyroid cartilage. Typically, there is no vasculature near the superior aspect of the cricoid cartilage, although there is a small percentage of patients who have an inferior thyroid artery variant called a *thyroid IMA* artery, which arises from the aortic arch or, in some cases, the subclavian artery and passing over the inferior portion of the membrane.[135]

There are 2 techniques for the surgical cricothyroidotomy: open cricothyroidotomy and Seldinger cricothyroidotomy (**Boxes 2** and **3**).[136] The Seldinger technique has been shown to be quicker as well as has fewer complications.[137,138] Typically, cricothyroidotomy kits come already prepared, with the Melker kit (Cook Critical Care, Bloomington, IN, USA) being the most popular because it allows for both an open and Seldinger technique. However, if your institution does not have a commercially available kit, a kit should be prepared ahead of time, being mindful that the inner diameter of the tube should NOT exceed 6.0 mm. A 6.0- or 5.0-mm internal diameter cuffed ET tube should be used if a cuffed emergency cricothyroidotomy catheter is not

Box 2
Procedure for open cricothyroidotomy approach

The clinician should stand on one side of the patient. A right-handed clinician should stand on the right and a left-handed clinician should stand on the left.

Feel for the thyroid prominence at the midline of the thyroid cartilage and then roll the index finger caudally by 1 to 2 cm until a small hollow is felt. This is the cricothyroid membrane.

Use the thumb and middle finger of the nondominant hand to stabilize the 2 cartilages.

A vertical skin incision is then made in the midline of the region between the thyroid cartilage and cricoid cartilage. (A vertical incision is made to avoid vasculature and can be extended if it is too high or too low.)

Once the cricothyroid membrane is exposed, turn the scalpel horizontally and perforate at the midline inferior portion of the membrane using a horizontal stabbing motion approximately 1 cm deep to avoid complications. A horizontal incision is made so as not to cut the cricoid cartilage as one might with a vertical incision.

Insert the back handle of the scalpel into the cricothyroid membrane and rotate it 90° to widen the opening.

Place the ET tube in the opening and inflate the balloon as in a traditional intubation. Connect the ET tube to the BVM and confirm placement with standard protocol.

Secure the ET tube with adhesive tape.

Obtain a chest radiograph to verify placement.

Data from Farcy DA, Chiu MC, Flaxman A, et al. Critical care emergency medicine. New York: McGraw Hill Professional; 2011.

Box 3
Procedure for Seldinger cricothyroidotomy approach

Open the kit and insert the dilator with the wire into the airway catheter.

Locate the cricothyroid membrane as stated before.

Attach the sheath to the needle and fill the syringe with a small amount of water. Insert the needle into the cricothyroid membrane pointing toward the feet at a 45 to 50° angle. Gently puncture until air bubbles appear in the syringe.

As soon as air bubbles appear, advance the sheath at a 45° angle, knowing that an overzealous advancement may get the sheath stuck on the posterior aspect of the cricoid cartilage.

Withdraw the syringe and advance the guidewire through the sheath. Then remove the sheath when the guidewire is advanced far enough.

Take the 15-blade scalpel; create a 0.5-cm vertical skin incision on both sides of the wire.

Insert the external end of the wire into the dilator (which you had already placed into the airway catheter in step 1) and insert them as a unit through the cricothyroid membrane, following the curvature of the dilator. Advance until the catheter is flush against the skin.

Once in place, remove the dilator and inflate the cuff.

Secure the cricothyroidotomy airway catheter with the provided wrap.

Data from Farcy DA, Chiu MC, Flaxman A, et al. Critical care emergency medicine. New York: McGraw Hill Professional; 2011.

available. Be aware that if an ET tube is being used, it is difficult to secure and may end up with a right main stem bronchus intubation. It is often prudent to be aware of the cricothyrotomy kit in your emergency department as well as its equipment before a failed airway has presented itself.

MECHANICAL VENTILATION

With the increasing demand on emergency departments and prolonged boarding times of ICU patients in the emergency department, the management of mechanical ventilation (MV) is becoming an ever more crucial skills for an emergency physician. It is critical that an emergency physician understand the basics of MV for varying disease processes, with the special consideration that every patient is different.

To date, there are no fixed indications for MV; but generally patients are intubated for respiratory failure, protection of the airway from potential aspiration of various causes, and predicted clinical course of facilitating either a workup or a definitive treatment. Placement of the ET tube has now removed all protective functions of the upper airway: warming of air, air filtration, prevention of aspiration, and removal of secretions. Additionally, MV is providing paradoxic breathing in which positive pressure is being forced into sensitive lung tissues allowing for possible ventilator-induced lung injury, acute lung injury, and barotrauma/volutrauma.[139] Nonetheless, with a general understanding of MV, one can navigate through the hazards of critically ill intubated patients.

The most crucial iatrogenic injury associated with MV is ventilator-induced lung injury.[139] In lung diseases that require MV, the underlying disease is usually not distributed uniformly throughout the lungs. Thus, inflation volumes are preferentially shunted toward normal lungs, which may cause hyperinflation, producing stress fractures at the alveolar-capillary interface. This condition may be a result of excessive alveolar pressures (barotrauma) or excessive alveolar volumes (volutrauma).[139] In turn, the fractures may cause increased inflammation in the normal lung volumes leading to an acute respiratory distress syndrome (ARDS)–like picture.

As a result, a large study published in the *New England Journal of Medicine* demonstrated in more than 800 patients that ventilation with low tidal volumes was associated with a 9% absolute reduction in mortality when the end-inspiratory plateau pressure was more than 30 cm H_2O.[140] In essence, low volume (6 mL/kg) is now recommended for all patients with ARDS and is now considered a beneficial strategy in all patients with acute respiratory failure.[141] Additionally, low lung volumes cause repeated opening and closing of the alveoli at the end of expiration resulting in possible acute lung injury. To ameliorate this, adding positive end-expiratory pressure (PEEP) stents opens the airways and prevents further injury. A sample protocol designed to reduce ventilator-induced lung injury is described in **Box 4**.[142,143]

POSTINTUBATION SEDATION

Once patients are intubated and MV management has begun, it is important to minimize discomfort. Despite the tradition of a long-term paralytic followed by a benzodiazepine for postintubation management, there is now a push to move toward a pain-first paradigm.[144] The goal is to optimize analgesia and then add in sedative agents.

Typically, after intubation or during rapid sequence intubation, providing a fentanyl or morphine bolus will address pain issues and perhaps keep you ahead of the game. Once analgesia has been initiated, the clinician has to decide what sedative/analgesic combination to provide. This depends on the type of pathologic condition patients have on intubation. Sedation choices are provided in **Table 5**.

Box 4
Protocol for lung protective ventilation

1. Select assist-control mode and fraction of inspired oxygen (FIO_2) = 100%
2. Set initial tidal volume (Vt) at 8 mL/kg using the patient's predicted body weight (PBW)
   a. Men: PBW = 50 + (2.3 × [height in inches − 60])
   b. Women: PBW = 45.5 + (2.3 × [height in inches − 60])
3. Select respiratory rate (RR) to achieve preventilator minute ventilation, but do not exceed RR = 35/min
4. Add PEEP at 5 to 7 cm H_2O
5. Reduce Vt by 1 mL/kg every 2 hours until Vt = 6 mL/kg
6. Adjust FIO_2 and PEEP to keep PaO_2 greater than 55 mm Hg or arterial oxygen saturation greater than 88%
7. When Vt is decreased to 6 mL/kg, measure
   a. Plateau pressure
   b. Arterial PCO_2 and pH

Remember that this is a general guideline. Each patient has a unique pathologic profile and will need ventilator adjustments specific for their pathologic condition (ie, asthmatic intubations will need to have a lower respiratory rate to allow exhalation of an obstructive lung disease process).

Data from Marino PL. The ICU book. 3rd edition. Philadelphia: Lippincott Williams and Wilkins; 2007.

Table 5
Sedation choices for mechanical ventilation

Drug	Characteristics	Indications	Precautions
Midazolam	Dosage: 1–5 mg Onset: 1–4 min Duration: 30–60 min Maintenance dosage: 1–8 mg/h Drip titration: 1 mg/h	Typically used with fentanyl for sedation; medical patients who are hypotensive (may need to start pressors); patients with delirium tremens if propofol is not available	May cause hypotension with drug bolus; prolonged duration in renal and hepatic failure
Propofol	Dosage: Bolus not recommended Onset: 1–2 min Duration: 30 min Maintenance dosage: 25–50 mcg/kg/min Drip titration: 10 mcg/kg/min	Typically used with fentanyl for sedation; good for critically ill patients with neurological problems	Possible hypotension with bolus, bradycardia, hypertriglyceridemia, pancreatitis, and propofol-related infusion syndrome
Ketamine	Dosage: 25–50 mg Onset: 30 sec Duration: 5–10 min Maintenance dosage: 1–3 mg/kg/min Drip titration: 0.25–0.5 mg/kg/min	Typically used with fentanyl for sedation; good for trauma patients who are hypotensive	Possible emergence reaction; purposeless and tonic-clonic movements may occur

Abbreviation: IV, intravenous.

Data from Casabar E, Portell J. Barnes Jewish Hospital the tool book for drug dosage and usage guidelines. St Louis (MO): The Department of Pharmacy Barnes Jewish Hospital; 2011.

SUMMARY

Airway management is a critical skill for emergency physicians. Careful airway assessment and preplanning are essential in determining which patients require invasive airway management and what equipment will be required to successfully manage that patient's airway. Airway management is a team-based procedure, and the emergency physician must be receptive and responsive to team input to maximize the safety of the procedure.

REFERENCES

1. Walls RM. The emergency airway algorithms. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 22–34.
2. Murphy MF, Doyle DJ. Airway evaluation. In: Hung OR, Murphy MF, editors. Management of the difficult and failed airway. New York: McGraw-Hill; 2008. p. 1–14.
3. Langeron O, Masso E, Huraux C, et al. Prediction of difficult mask ventilation. Anesthesiology 2000;92(5):1229–36.
4. Yildiz TS, Solak M, Toker K. The incidence and risk factors of difficult mask ventilation. J Anesth 2005;19(1):7–11.
5. Murphy MF, Walls RM. Identification of the difficult and failed airway. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 81–93.
6. Reed MJ, Rennie LM, Dunn MJ, et al. Is the 'LEMON' method an easily applied emergency airway assessment tool? Eur J Emerg Med 2004;11(3):154–7.
7. Callahan J. Pulse oximetry in emergency medicine. Emerg Med Clin North Am 2008;26(4):869–79.
8. Howell M. Pulse oximetry: an audit of nursing and medical staff understanding. Br J Nurs 2002;11(3):191–7.
9. Elliot M, Tate R, Page K. Do clinicians know how to use pulse oximetry? A literature review and clinical implications. Aust Crit Care 2006;19(4):139–44.
10. Nagler J, Baruch K. Capnography: a valuable tool for airway management. Emerg Med Clin North Am 2008;26(4):881–97.
11. Taryle DA, Chandler JE, Good JT, et al. Emergency room intubations - complications and survival. Chest 1979;75(5):541–3.
12. Sakles JC, Laurin EG, Rantapaa AA, et al. Airway management in the emergency department: a one-year study of 610 tracheal intubations. Ann Emerg Med 1998;31(3):325–32.
13. Wongyingsinn M, Songarj P, Assawinvinijkul T. A prospective observational study of tracheal intubation in an emergency department in a 2300-bed hospital of a developing country in a one-year period. Emerg Med J 2009;26(8):604–8.
14. Antonescu-Turcu A, Parthasarathy S. CPAP and Bi-level PAP therapy: new and established roles. Respir Care 2010;55(9):1216–28.
15. Drinker PA, McKhann CF. The iron lung: first practical means of respiratory support. JAMA 1986;255(11):1476–80.
16. Kosowsky JM, Storrow AB, Carleton SC. Continuous and bi-level positive airway pressure in the treatment of acute cardiogenic pulmonary edema. Am J Emerg Med 2000;18(1):91–5.
17. Marik PE. Handbook of evidence-based critical care. 2nd edition. Springer Science and Business Media, New York: LLC; 2010.

18. Keenan SP, Sinuff T, Cook DJ, et al. Which patients with acute exacerbation of chronic obstructive pulmonary disease benefit from noninvasive positive-pressure ventilation? A systematic review of the literature. Ann Intern Med 2003;138(11):861–70.
19. Ram FS, Picot J, Lightowler J, et al. Non-invasive positive pressure ventilation for treatment of respiratory failure due to exacerbations of chronic obstructive pulmonary disease. Cochrane Database Syst Rev 2004;(3):CD004104.
20. Brochard L, Mancebo J, Wysocki M, et al. Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease. N Engl J Med 1995; 333(13):817–22.
21. Kramer N, Meyer TJ, Meharg J, et al. Randomized, prospective trial of noninvasive positive pressure ventilation in acute respiratory failure. Am J Respir Crit Care Med 1995;151(6):1799–806.
22. Wysocki M, Tric L, Wolff MA, et al. Noninvasive pressure support ventilation in patients with acute respiratory failure: a randomized comparison with conventional therapy. Chest 1995;107(3):761–8.
23. Mehta S, Jay GD, Woolard RH, et al. Randomized, prospective trial of bilevel versus continuous positive airway pressure in acute pulmonary edema. Crit Care Med 1997;25(4):620–8.
24. Lin M, Yang YF, Chiang HT, et al. Reappraisal of continuous positive airway pressure therapy in acute cardiogenic pulmonary edema: short-term results and long-term follow-up. Chest 1995;107(5):1379–86.
25. Winck JC, Azevedo LF, Costa-Pereira A, et al. Efficacy and safety of non-invasive ventilation in the treatment of acute cardiogenic pulmonary edema – a systematic review and meta-analysis. Crit Care 2006;10(2):R69.
26. Ho KM, Wong K. A comparison of continuous and bi-level positive airway pressure non-invasive ventilation in patients with acute cardiogenic pulmonary oedema: a meta-analysis. Crit Care 2006;10(2):R49.
27. Weng CL, Zhao YT, Liu QH, et al. Meta-analysis: noninvasive ventilation in acute cardiogenic pulmonary edema. Ann Intern Med 2010;152(9):590–600.
28. Hilbert G, Gruson D, Vargas F, et al. Noninvasive ventilation in immunosuppressed patients with pulmonary infiltrates, fever, and acute respiratory failure. N Engl J Med 2001;344(7):481–7.
29. Marik PE. Non-invasive positive-pressure ventilation in patients with malignancy. Am J Hosp Palliat Care 2007;24(5):417–21.
30. Nava S, Ambrosino N, Clini E, et al. Noninvasive mechanical ventilation in the weaning of patients with respiratory failure due to chronic obstructive pulmonary disease: a randomised, controlled trial. Ann Intern Med 1998;128(9):721–8.
31. Girault C, Daudenthun I, Chevron V, et al. Non-invasive ventilation as a systematic extubation and weaning technique in acute-on-chronic respiratory failure: a prospective, randomized controlled study. Am J Respir Crit Care Med 1999; 160(1):86–92.
32. Ferreyra GP, Baussano I, Squadrone V, et al. Continuous positive airway pressure for treatment of respiratory complications after abdominal surgery: a systematic review and meta-analysis. Ann Surg 2008;247(4):617–26.
33. Squadrone V, Coha M, Cerutti E, et al. Continuous positive airway pressure for treatment of postoperative hypoxemia: a randomized controlled trial. JAMA 2005;293(5):589–95.
34. Gupta D, Nath A, Agarwal R, et al. A prospective randomized controlled trial on the efficacy of noninvasive ventilation in severe acute asthma. Respir Care 2010; 55(5):536–43.

35. Ram FS, Wellington S, Rowe B, et al. Non-invasive positive pressure ventilation for treatment of respiratory failure due to severe acute exacerbations of asthma. Cochrane Database Syst Rev 2005;(3):CD004360.
36. Mehta S, Hill NS. Noninvasive ventilation: state of the art. Am J Respir Crit Care Med 2001;163(2):540–77.
37. Confalonieri M, Garuti G, Cattaruzza M, et al. A chart of failure risk for noninvasive ventilation in patients with COPD exacerbation. Eur Respir J 2005;25(2): 348–55.
38. Davies AE, Stone SP, Kidd D, et al. Pharyngeal sensation and gag reflex in healthy subjects. Lancet 1995;345(8948):487–8.
39. Sexton JB, Berenholtz SM, Goeschel CA, et al. Assessing and improving safety climate in a large cohort of intensive care units. Crit Care Med 2011;39(5):934–9.
40. Jaber S, Jung B, Corne P, et al. An intervention to decrease complications related to endotracheal intubation in the intensive care unit: a prospective, multiple-center study. Intensive Care Med 2010;36(2):248–55.
41. Cook TM, Woodall N, Harper J, et al. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. Br J Anaesth 2011;106(5):632–42.
42. Rall M. Safety culture and crisis resource management in airway management: general principles to enhance patient safety in critical airway situations. Best Pract Res Clin Anaesthesiol 2005;19(4):539–57.
43. Carleton SC, Reardon RF, Brown CA. Bag-mask ventilation. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 79–91.
44. Chandler M, Crawley BE. Rationalization of the selection of tracheal tubes. Br J Anaesth 1986;58(1):111–6.
45. Luten RC, Wears RL, Broselow J, et al. Length-based endotracheal tube and emergency equipment in pediatrics. Ann Emerg Med 1992;21(8):900–4.
46. Griesdale DE, Liu D, McKinney J, et al. Glidescope(®) video-laryngoscopy versus direct laryngoscopy for endotracheal intubation: a systematic review and meta-analysis. Can J Anaesth 2012;59(1):41–52.
47. Sternbach G. Ivan Magill: forceps for intratracheal anesthesia. J Emerg Med 1984;1(6):543–5.
48. Arthur W, Bennett W, Stanush P, et al. Factors that influence skill decay and retention: a quantitative review and analysis. Hum Perform 1998;11(1):57–101.
49. Bond WF, Lammers RL, Spillane LL, et al. The use of simulation in emergency medicine: a research agenda. Acad Emerg Med 2007;14(4):353–63.
50. McLaughlin SA, Doezema D, Sklar DP. Human simulation in emergency medicine training: a model curriculum. Acad Emerg Med 2002;9(11):1310–8.
51. Batra YK, Mathew P. Airway management with endotracheal intubation (including awake intubation and blind intubation). Indian J Anaesth 2005; 49(4):263–8.
52. Reardon RF, Carelton SC, Brown CA. Direct laryngoscopy. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 121–38.
53. Adnet F, Baillard C, Borron SW, et al. Randomized study comparing the "sniffing position" with simple head extension for laryngoscopic view in elective surgery patients. Anesthesiology 2001;95(4):836–41.
54. Butler J, Sen A. Best evidence topic report. Cricoid pressure in emergency rapid sequence induction. Emerg Med J 2005;22(11):815–6.

55. American Heart Association. ACLS provider manual supplementary material. In: Sinz E, Navarro K, editors. Advanced cardiovascular life support provider manual. Dallas(TX): American Heart Association; 2011. p. 1–86.
56. Hirabayashi Y, Otsuka Y. The BURP manoeuvre for better glottic view using the paediatric GlideScope. Anaesthesia 2010;65(8):862–3.
57. Takahata O, Kubota M, Mamiya K, et al. The efficacy of the “BURP” maneuver during a difficult laryngoscopy. Anesth Analg 1997;84(2):419–21.
58. Levitan RM, Kinkle WC, Levin WJ, et al. Laryngeal view during laryngoscopy: a randomized trial comparing cricoid pressure, backward-upward-rightward pressure, and bimanual laryngoscopy. Ann Emerg Med 2006; 47(6):548–55.
59. Li J, Murphy-Lavoie H, Bugas C, et al. Complications of emergency intubation with and without paralysis. Am J Emerg Med 1999;17(2):141–3.
60. Finucane BT, Tsui BCH, Santora AH. Complications of airway management. In: Finucane BT, Tsui BC, Santora AH, editors. Principles of airway management. New York: Springer; 2011. p. 683–730.
61. Li J. Capnography alone is imperfect for endotracheal tube placement confirmation during emergency intubation. J Emerg Med 2001;20(3):223–9.
62. Stone DJ, Gal TJ. Airway management. In: Miller RD, editor. Anesthesia. New York: Churchill Livingstone; 2000. p. 1414–51.
63. Grmec S. Comparison of three different methods to confirm tracheal tube placement in emergency intubation. Intensive Care Med 2002;28(6):701–4.
64. Deiorio NM. Continuous end-tidal carbon dioxide monitoring for confirmation of endotracheal tube placement is neither widely available nor consistently applied by emergency physicians. Emerg Med J 2005;22(7):490–3.
65. Sim SS, Lien WC, Chou HC, et al. Ultrasonographic lung sliding sign in confirming proper endotracheal intubation during emergency intubation. Resuscitation 2012;83(3):307–12.
66. Brun PM, Bessereau J, Cazes N, et al. Lung ultrasound associated to capnography to verify correct endotracheal tube positioning in prehospital. Am J Emerg Med 2011. [Epub ahead of print].
67. Pfeiffer P, Rudolph SS, Børglum J, et al. Temporal comparison of ultrasound vs. auscultation and capnography in verification of endotracheal tube placement. Acta Anaesthesiol Scand 2011;55(10):1190–5.
68. Weaver B, Lyon M, Blaivas M. Confirmation of endotracheal tube placement after intubation using the ultrasound sliding lung sign. Acad Emerg Med 2006;13(3):239–44.
69. Shah KH, Kwong BM, Hazan A, et al. Success of the gum elastic bougie as a rescue airway in the emergency department. J Emerg Med 2011;40(1):1–6.
70. Arora MK, Karamchandani K, Trikha A. Use of a gum elastic bougie to facilitate blind nasotracheal intubation in children: a series of three cases. Anaesthesia 2006;61(3):291–4.
71. Arisaka H, Sakuraba S, Furuya M, et al. Application of gum elastic bougie to nasal intubation. Anesth Prog 2010;57(3):112–3.
72. Marciniak D, Smith CE. Emergent retrograde tracheal intubation with a gum-elastic bougie in a trauma patient. Anesth Analg 2007;105(6):1720–1.
73. Smith MD, Katrinchak J. Use of a gum elastic bougie during surgical crichothyrotomy. Am J Emerg Med 2008;26(6):738.
74. Nolan JP, Wilson ME. Orotracheal intubation in patients with potential cervical spine injuries. An indication for the gum-elastic bougie. Anaesthesia 1993; 48(7):630–3.

75. Sime J, Bailitz J, Moskoff J. The bougie: an inexpensive lifesaving airway device. J Emerg Med 2011. [Epub ahead of print].
76. Kidd JF, Dyson A, Latto IP. Successful difficult intubation. Use of the gum elastic bougie. Anaesthesia 1988;43(6):437–8.
77. Phelan MP. Use of the endotracheal bougie introducer for difficult intubations. Am J Emerg Med 2004;22(6):479–82.
78. Hernandez MR, Klock PA Jr, Ovassapian A. Evolution of the extraglottic airway: a review of its history, applications, and practical tips for success. Anesth Analg 2012;114(2):349–68.
79. Parmet JL, Colonna-Romano P, Horrow JC, et al. The laryngeal mask airway reliably provides rescue ventilation in cases of unanticipated difficult tracheal intubation along with difficult mask ventilation. Anesth Analg 1998;87(3):661–5.
80. Jones JR. Laryngeal mask airway: an alternative for the difficult airway. AANA J 1995;63(5):444–9.
81. Schälte G, Stoppe C, Aktas M, et al. Laypersons can successfully place supraglottic airways with 3 minutes of training. A comparison of four different devices in the manikin. Scand J Trauma Resusc Emerg Med 2011;19:60.
82. Gerstein NS, Braude DA, Hung O, et al. The Fastrach Intubating Laryngeal Mask Airway: an overview and update. Can J Anaesth 2010;57(6):588–601.
83. Fukutome T, Amaha K, Nakazawa K, et al. Tracheal intubation through the intubating laryngeal mask airway (LMA-Fastrach) in patients with difficult airways. Anaesth Intensive Care 1998;26(4):387–91.
84. Rosenblatt WH, Murphy M. The intubating laryngeal mask: use of a new ventilating-intubating device in the emergency department. Ann Emerg Med 1999;33(2):234–8.
85. Levitan RM, Ochroch EA, Stuart S, et al. Use of the intubating laryngeal mask airway by medical and nonmedical personnel. Am J Emerg Med 2000;18(1): 12–6.
86. Young B. The intubating laryngeal-mask airway may be an ideal device for airway control in the rural trauma patient. Am J Emerg Med 2003;21(1):80–5.
87. Ferson DZ, Rosenblatt WH, Johansen MJ, et al. Use of the intubating LMA-Fastrach in 254 patients with difficult-to-manage airways. Anesthesiology 2001;95(5):1175–81.
88. Wakeling HG, Bagwell A. The intubating laryngeal mask (ILMA) in an emergency failed intubation. Anaesthesia 1999;54(3):305–6.
89. Murdoch JA. Emergency tracheal intubation using a gum elastic bougie through a laryngeal mask airway. Anaesthesia 2005;60(6):626–7.
90. Hubble MW, Wilfong DA, Brown LH, et al. A meta-analysis of prehospital airway control techniques part II: alternative airway devices and cricothyrotomy success rates. Prehosp Emerg Care 2010;14(4):515–30.
91. Deakin CD, Nolan JP, Soar J, et al. European resuscitation council guidelines for resuscitation 2010 section 4. Adult advanced life support. Resuscitation 2010; 81(10):1305–52.
92. Russi CS, Miller L, Hartley MJ. A comparison of the King-LT to endotracheal intubation and Combitube in a simulated difficult airway. Prehosp Emerg Care 2008; 12(1):35–41.
93. Guyette FX, Wang H, Cole JS. King airway use by air medical providers. Prehosp Emerg Care 2007;11(4):473–6.
94. Hagberg C, Bogomony Y, Gilmore C, et al. An evaluation of the insertion and function of a new supraglottic airway device, the King LT, during spontaneous ventilation. Anesth Analg 2006;102(2):621–5.

95. Genzwuerker HV, Vollmer T, Ellinger K. Fibreoptic tracheal intubation after placement of the laryngeal tube. Br J Anaesth 2002;89(5):733–8.
96. Lutes M, Worman DJ. An unanticipated complication of a novel approach to airway management. J Emerg Med 2010;38(2):222–4.
97. Bentsianov BL, Parhiscar A, Azer M, et al. The role of fiberoptic nasopharyngoscopy in the management of the acute airway in angioneurotic edema. Laryngoscope 2000;110(12):2016–9.
98. Agrawal P, Gupta B, D'souza N, et al. Fiberoptic bronchoscope assisted difficult airway management in maxillofacial trauma. Ann Maxillofac Surg 2011;1(1):95–6.
99. Wang HE, Kupas DF, Greenwood MJ, et al. An algorithmic approach to prehospital airway management. Prehosp Emerg Care 2005;9(2):145–55.
100. Godwin SA. Blind intubation techniques. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 185–92.
101. Rosen CL, Wolfe RE, Chew SE, et al. Blind nasotracheal intubation in the presence of facial trauma. J Emerg Med 1997;15(2):141–5.
102. Murphy MF, DeBlieux PMC. Flexible endoscopic intubation. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 166–73.
103. Gwinnutt CL. The interface between anaesthesia and emergency medicine. Emerg Med J 2001;18(5):325–6.
104. Walls RM. Rapid sequence intubation. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 220–32.
105. Baraka AS, Taha SK, Aouad MT, et al. Preoxygenation: comparison of maximal breathing and tidal volume breathing techniques. Anesthesiology 1999;91(3):612–6.
106. Farmery AD, Roe PG. A model to describe the rate of oxyhaemoglobin desaturation during apnoea. Br J Anaesth 1996;76(2):284–91.
107. Mort TC. Preoxygenation in critically ill patients requiring emergency tracheal intubation. Crit Care Med 2005;33(11):2672–5.
108. Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. Ann Emerg Med 2012;59(3):165–75.
109. Baker PA, Weller JM, Greenland KB, et al. Education in airway management. Anaesthesia 2011;66(Suppl 2):101–11.
110. Singh H, Vichitvejpaisal P, Gaines GY, et al. Comparative effects of lidocaine, esmolol, and nitroglycerin in modifying the hemodynamic response to laryngoscopy and intubation. J Clin Anesth 1995;7(1):5–8.
111. Donegan MF, Bedford RF. Intravenously administered lidocaine prevents intracranial hypertension during endotracheal suctioning. Anesthesiology 1980;52(6):516–8.
112. Chraemmer-Jørgensen B, Høilund-Carlsen PF, Marving J, et al. Lack of effect of intravenous lidocaine on hemodynamic responses to rapid sequence induction of general anesthesia: a double-blind controlled clinical trial. Anesth Analg 1986;65(10):1037–41.
113. Walls RM. Management of the difficult airway in the trauma patient. Emerg Med Clin North Am 1998;16(1):45–61.
114. de Nadal M, Munar F, Poca MA, et al. Cerebral hemodynamic effects of morphine and fentanyl in patients with severe head injury: absence of correlation to cerebral autoregulation. Anesthesiology 2000;92(1):11–9.

115. McAuliffe G, Bissonnette B, Boutin C. Should the routine use of atropine before succinylcholine in children be reconsidered? Can J Anaesth 1995;42(8):724–9.
116. Fastle RK, Roback MG. Pediatric rapid sequence intubation: incidence of reflex bradycardia and effects of pretreatment with atropine. Pediatr Emerg Care 2004;20(10):651–5.
117. Reynolds SF, Heffner J. Airway management of the critically ill patient: rapid-sequence intubation. Chest 2005;127(4):1397–412.
118. Sivilotti ML, Filbin MF, Murray HE, et al. Does the sedative agent facilitate emergency rapid sequence intubation? Acad Emerg Med 2003;10(6):612–20.
119. Bergen JM, Smith DC. A review of etomidate for rapid sequence intubation in the emergency department. J Emerg Med 1997;15(2):221–30.
120. Yeung JK, Zed PJ. A review of etomidate for rapid sequence intubation in the emergency department. CJEM 2002;4(3):194–8.
121. Sih K, Campbell SG, Tallon JM, et al. Ketamine in adult emergency medicine: controversies and recent advances. Ann Pharmacother 2011;45(12):1525–34.
122. Sehdev RS, Symmons DA, Kindl K. Ketamine for rapid sequence induction in patients with head injury in the emergency department. Emerg Med Australas 2006;18(1):37–44.
123. Hudetz JA, Pagel PS. Neuroprotection by ketamine: a review of the experimental and clinical evidence. J Cardiothorac Vasc Anesth 2010;24(1):131–42.
124. Bourgoin A, Albanèse J, Léone M, et al. Effects of sufentanil or ketamine administered in target-controlled infusion on the cerebral hemodynamics of severely brain-injured patients. Crit Care Med 2005;33(5):1109–13.
125. Bar-Joseph G, Guilburd Y, Tamir A, et al. Effectiveness of ketamine in decreasing intracranial pressure in children with intracranial hypertension. J Neurosurg Pediatr 2009;4(1):40–6.
126. Martyn JA, Richtsfeld M. Succinylcholine-induced hyperkalemia in acquired pathologic states: etiologic factors and molecular mechanisms. Anesthesiology 2006;104(1):158–69.
127. Burkle CM, Walsh MT, Harrison BA, et al. Airway management after failure to intubate by direct laryngoscopy: outcomes in a large teaching hospital. Can J Anaesth 2005;52(6):634–40.
128. Agro F, Hung OR, Cataldo R, et al. Lightwand intubation using the Trachlight: a brief review of current knowledge. Can J Anaesth 2001;48(6):592–9.
129. Hung OR, Pytka A, Morris I, et al. Clinical trial of a new lightwand device (Trachlight) to intubate the trachea. Anesthesiology 1995;83(3):509–14.
130. Kovacs G, Law JA, McCrossin C, et al. A comparison of a fiberoptic stylet and a bougie as adjuncts to direct laryngoscopy in a manikin-simulated difficult airway. Ann Emerg Med 2007;50(6):676–85.
131. Dhara SS. Retrograde tracheal intubation. Anaesthesia 2009;64(10):1094–104.
132. Elliott DS, Baker PA, Scott MR, et al. Accuracy of surface landmark identification for cannula cricothyroidotomy. Anaesthesia 2010;65(9):889–94.
133. Bennett JD, Guha SC, Sankar AB. Cricothyrotomy: the anatomical basis. J R Coll Surg Edinb 1996;41(1):57–60.
134. Murphy MF. Applied functional anatomy of the airway. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 36–44.
135. Won HS, Han SH, Oh CS, et al. Superior and middle thyroid arteries arising from the common carotid artery. Surg Radiol Anat 2011;33(7):645–7.
136. Farcy DA, Chiu MC, Flaxman A, et al. Critical care emergency medicine. New York: McGraw Hill Professional; 2011.

137. Isaacs JH Jr, Pedersen AD. Emergency cricothyroidotomy. Am Surg 1997;63(4): 346–9.
138. Schaumann N, Lorenz V, Schellongowski P, et al. Evaluation of Seldinger technique emergency cricothyroidotomy versus standard surgical cricothyroidotomy in 200 cadavers. Anesthesiology 2005;102(1):7–11.
139. Richard JD, Dreyfuss D, Saumon G. Ventilation-induced lung injury. Eur Respir J 2003;22(Suppl 42):2s–9s.
140. The Acute Respiratory Distress Syndrome Network. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N Engl J Med 2000;342(18):1301–8.
141. Brower RG, Lanken PN, MacIntyre N, et al. Higher vs. lower positive end-expiration pressures in patients with the acute respiratory distress syndrome. N Engl J Med 2004;351(4):327–36.
142. NHLBI ARDS Network. Ventilator protocol card. Available at: http://www.ardsnet.org/node/77791. Accessed January 24, 2012.
143. Marino PL. The ICU book. 3rd edition. Philadelphia: Lippincott Williams and Wilkins; 2007.
144. Strom T, Martinussen T, Toft P. A protocol of no sedation for critically ill patients receiving mechanical ventilation: a randomised trial. Lancet 2010;375(9713): 475–80.