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Airway Management in Trauma

Management of the airway is given the ultimate place of importance in resuscitations. Virtually all algorithms begin with attention to and protection of the airway. The skill of the intubator is tested in the trauma patient whose airway is often compromised by multiple complicating factors, including hemodynamic instability from multi-organ injury, cervical spine fractures, and direct trauma.

— The Editor

Introduction

The process of airway management has evolved considerably to include rapid sequence intubation (RSI), the use of various procedures, and sophisticated devices designed to assist in the placement of an endotracheal tube. This article summarizes the basic concepts of airway management, the technique of RSI, and post-intubation management in trauma patients.

Indications for Respiratory Intervention

The decision to intubate a patient in the emergency department (ED) can be the most significant and definitive step in the care of the trauma patient. The primary goals of intervening are to improve gas exchange, relieve respiratory distress by decreasing the work of breathing, and protect against aspiration. Secondary goals range from control of violent behavior in a patient with excited delirium to the delivery of heated, humidified oxygen to facilitate core rewarming.

Respiratory Failure

Respiratory failure occurs when the patient is unable to oxygenate or ventilate adequately to meet physiologic needs. The decision to intervene is based on clinical judgment in most cases with signs of respiratory distress. Rarely, abnormalities found on blood gas analysis will be available. However, if blood gas values are available, a pH < 7.3 resulting from hypoventilation should prompt intervention. When making a decision based on abnormal blood gas analysis, carbon dioxide retention with a $PaCO_2$ > 55 (with previously normal $PaCO_2$) or a rise in $PaCO_2$ by 10 acutely in chronic obstructive pulmonary disease (COPD) can be an indication for possible intervention. Oxygenation failure often is defined as the inability to maintain a PaO_2 of 60 mmHg on an FiO_2 of > 40%.

Respiratory Muscle Fatigue

Increased work of breathing seen with decreased lung compliance (pulmonary contusions, pneumothorax, atelectasis) and increased airway resistance (bronchospasm, excessive airway secretions) can contribute to early fatigue of respiratory muscles.

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EXECUTIVE SUMMARY

- The primary goals of airway intervention are to improve gas exchange, relieve respiratory distress by decreasing the work of breathing, and protect against aspiration.
- Clues to impending airway obstruction include hoarseness, stridor, poor handling of secretions, falling pulse oximetry, progressive rise in end-tidal CO_2, decline in mental status or agitation, and expanding mouth or neck hematomas.
- The Ps of Rapid Sequence Intubation, as described by Walls and Murphy, is widely taught and accepted. The "Ps" have been modified and updated over the years, reflecting new research and improved ED experience with RSI. The algorithm is derived from their approach. It includes: plan B, prepare, predict, position, preoxygenate, put to sleep, paralyze, pass the tube, prove placement, post-intubation management, and problem solving.
- Passive oxygenation, also known as apneic oxygenation, provides real oxygen delivery to the patient and can help maintain saturations above 90% for an extended period of time.
- In the emergency department, patients with impending apnea often will not tolerate a five-minute period of preoxygenation. Instead, eight vital capacity breaths of 100% oxygen may serve the same nitrogen washout function and effectively retard apnea-induced hemoglobin desaturation.
- A quick and easy mnemonic to help remember the major causes of fixable problems when a patient deteriorates after intubation is "DOPES": Dislodged endotracheal tube, Obstruction, Pneumothorax, Equipment failure, Stacked breaths.

Aspiration Protection

When a patient appears obtunded, endotracheal intubation becomes vital to decrease the risk of aspiration and its attendant complications. Gag reflex can be absent in a significant number of normal patients, and this alone should not necessarily prompt intubation.

Mechanical Obstruction

Distortion of the airway can occur in a variety of traumatic injuries. In cases in which there is impending airway obstruction or in which obstruction has already occurred, the decision to intervene is a forgone conclusion. With more subtle injury patterns, an airway may be intact at the moment, but the risk for potential obstruction may exist. This situation is typified in the case of thermal injury to the upper airway where developing edema has the potential to completely obstruct the larynx and other posterior pharyngeal structures. Other examples include direct laryngeal trauma and penetrating wounds to the neck. Hematomas from injury to the carotid artery can expand and distort the airway beyond laryngoscopic recognition. Clues to impending airway obstruction include hoarseness, stridor, poor handling of secretions, falling pulse oximetry, progressive rise in end tidal CO_2, decline in mental status or agitation, and expanding mouth or neck hematomas.

Core Rewarming

A patient can develop substantial hypothermia as the result of a traumatic injury occurring during cold weather or involving submersion in cold water. The principles of core rewarming place significant value on the delivery of heated, humidified oxygen to the lungs.[1] This is best accomplished via the use of an endotracheal tube. Humidified oxygen is heated to 45° C (113° F) and delivered continuously. A rise in core temperature of 1-2.5° C (1.8-4.3° F) per hour can be expected. Previous literature raising concerns that intubation may induce ventricular fibrillation has subsequently not been supported.

Initial Considerations for Airway Management in Trauma Patients

Consider Preexisting Difficult Airway

Patients will present to the ED with underlying preexisting anatomical variations that can complicate endotracheal intubation. It is imperative to evaluate the patient as thoroughly as possible before considering the use of a paralytic agent. A fundamental rule of airway management is to exercise caution when paralyzing (or deciding whether to paralyze) a patient who is expected to be an extremely difficult or impossible intubation, unless the intubator has a thoroughly determined plan to deal with the situation. Further, the ability to adequately mask ventilate should be considered when deciding on the type and method of airway intervention.

Trauma Immobilization

As in all trauma cases, careful consideration must be given to potential injury to the cervical spine and spinal cord. However, airway management still remains at the top of the resuscitation algorithm.

The physical process of trauma immobilization with a cervical collar and backboard can limit access to the airway and the anterior neck significantly. A properly placed collar inhibits opening of the mouth and, by intention, prevents repositioning of the head and neck. The collar can obstruct visualization of the anterior neck further and potentially lead one to miss laryngeal trauma or distortion of airway anatomy. Providers should log-roll patients off of a backboard if time allows, and they should remove the cervical collar and use inline stabilization during attempts at intubation.

Mechanical Distortion of the Airway or of Contiguous Structures

Direct trauma to the face, larynx, or thorax can alter the normal anatomic relationships of the airway structures and can increase the difficulty of intubation significantly. Likewise, cancers of the head and neck can distort the normal anatomy. Previous surgery to the larynx or neck can indicate a potential problem.

Rapid Sequence Intubation

RSI Overview

Airway management in the ED has evolved significantly over the years. Today in the ED, a myriad of techniques and tools are available that allow flexibility and best airway management practices to meet patient needs.

RSI is considered routine, with success rates reported at 99.7%.[2] The role of RSI in trauma currently is considered the method of choice for emergent airway control in the traumatized patient unless specific contraindications are present.[3]

RSI: The Technique

RSI is a method of quickly obtaining optimal intubating conditions via the delivery of an induction agent (to induce unconsciousness), followed in rapid succession by a paralytic agent. The goal of RSI is to facilitate the passage of an endotracheal tube into the trachea quickly and efficiently. RSI eliminates or reduces the need for ventilating the patient during the procedure unless oxygenation is impaired and the bag-valve mask must be used to maintain adequate saturation. The chance of aspiration of stomach contents during intubation also is minimized.

Various methods of teaching RSI have been developed, but the use of the Ps of Rapid Sequence Intubation, as described by Walls and Murphy,[4] is widely taught and accepted. The Ps have been modified and updated over the years, reflecting new research and improved ED experience with RSI. The approach presented below is derived from their approach with a few modifications. It includes: plan B, predict, prepare, preoxygenate, position, put to sleep, paralyze, pass the tube, prove placement, post-intubation management, and problem solving.

Plan B. The first P in this series refers to the predetermined plan for dealing with a difficult or failed orotracheal intubation. The emergency physician should plan for what to do if something should go wrong. In general, anesthesia research shows that 6-27% of patients will be difficult to intubate with direct laryngeal visualization.[5] Further, anesthesia literature shows a 0.1-0.4% incidence of intubation failure in patients who were judged a priori as likely to be successfully intubated. Dimitriou et al published a study in which an unanticipated failed intubation occurred in 0.4 % of cases (44 of 11,621 patients).[6] Because ED patients generally are sicker and undergo much more cursory and rapid preintubation evaluation, unexpected difficulties are more likely to be encountered. The National Emergency Airway Registry (NEAR III) showed in a series of 17,583 patients that 17% of cases required more than one attempt to successfully intubate the patient across all methods employed. The incidence of rescue cricothyrotomy was only 0.3% according to data from NEAR III.[2]

A complicated situation can become a disaster rapidly if no pre-implemented plan exists to deal with an anomaly. Implementation of an emergency airway cart, including difficult intubation equipment, can help avoid being without the appropriate equipment when needed.

Predict a Difficult Intubation. A thorough evaluation of the patient prior to attempts at laryngoscopy can help to predict a difficult intubation. Brown and Walls et al use the LEMON assessment as a tool to remember what to check during an evaluation.[5] (*See Table 1.*)

Regardless of individual evaluation of the airway and conclusions about the degree of anticipated difficulty of the impending intubation, the intubator mentally should plan to perform a cricothyrotomy. Discussing out loud the primary plan, plan B, and the conditions that will mandate an emergent cricothyrotomy will make it easier to move to a surgical airway when that is indicated. At times, the decision to perform a surgical airway is more difficult than the procedure itself. Performing a surgical airway should not be thought of as a failure, but rather as the next logical step in the failed airway algorithm.

Predictors of Difficulty With Cricothyrotomy. Finally, consideration should be given to potential difficulties with performing a cricothyrotomy. (*See Table 2.*)

Prepare. Taking the time to organize and inventory the working environment directly prior to actual intubation ensures that everything needed to perform the task will be available and in good working order. Not only does this preparation provide peace of mind and decrease stress levels, it can be a time- and life-saving investment.

Preparation includes the following:

- Thoroughly evaluate the patient for a potentially difficult intubation and for difficulty with bag-valve mask ventilation.
- Remove dentures.
- Bring the difficult airway cart to the bedside.
- Have the chosen laryngoscope blades ready (two sizes of Macintosh blades, two Miller blades).
- Check the light on the laryngoscope blades.
- Have video laryngoscopy device available at bedside.
- Verify the integrity of the balloon on the ET tube.
- Have large-bore suction ready at the bedside. A standard Yankauer tip, originally developed for operative use, has a small opening for gentle suction of blood. Large-bore catheters, such as the SSCOR DuCanto Catheter, have a larger internal diameter (0.26 inches) and can be used for suction-assisted laryngoscopy and airway decontamination for large-volume regurgitation.[8]
- Verify the integrity of intravenous (IV) access and start a second IV line. A disastrous situation can result when an induction agent is given, and the IV stops working before the paralytic agent can be pushed.
- Ensure the blood pressure cuff is on the contralateral limb.
- Have a chosen means to secure the endotracheal tube ready to implement.
- Have a color-change capnography or real-time capnometry device at bedside.
- Have post-intubation sedation prepared.

Preoxygenate. As early as possible, the patient should be placed on high-flow oxygen, as close as possible to 100% FiO_2. The goal is to replace the nitrogen in the patient's functional residual volume with oxygen. The healthy 70 kg adult can take as long as eight minutes to desaturate to 90%, whereas further desaturation from 90% to 0% can take

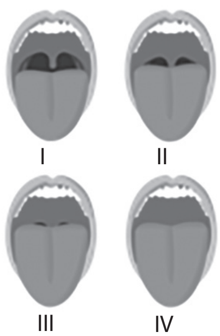
Table 1. LEMONS

L: Look externally

- Short muscular neck
- Full dentition
- Protruding upper incisors
- High-arched palate
- Receding mandible
- Severe facial trauma

E: Evaluate internally

The 3-3-2 rule describes the ideal external dimensions of the airway.
3: The opening of the jaw should be far enough to accommodate three fingers (3-4 cm).
3: The distance from the mentum to the hyoid bone should be at least three fingerbreadths
2: The distance from the floor of the mouth to the thyroid cartilage should be at least two fingerbreadths.



M: Mallampati

- Mallampati Class I: No difficulty: Soft palate, uvula, fauces, pillars visible
- Mallampati Class II: No difficulty: Soft palate, uvula, fauces visible
- Mallampati Class III: Moderate difficulty: Soft palate, base of uvula visible
- Mallampati Class IV: Major difficulty: Hard palate only visible

Figure: By Jmarchn (Own work) [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons

O: Obstruction

- Blood in the upper airway
- Foreign body
- Expanding hematoma
- Abscess
- Swelling of intraoral structures
- Laryngeal edema

N: Neck mobility

- Inability to flex or extend the neck (c-collar, arthritis, etc.)
- Cervical spine injury

S: Saturation

An oxygen saturation < 85% portends an impending desaturation that can occur very rapidly. This does not allow much time to perform the intubation.

only two minutes. This reflects the characteristic "slippery slope" found in the oxy-hemoglobin saturation curve. Heavier patients and small children typically will desaturate faster.[9] (*See Figure 1.*) The typical ED trauma patient requiring intubation does not have a normal cardiopulmonary function and, therefore, may fail to oxygenate optimally. Further, some pulmonary processes that impair oxygenation also will antagonize the effects of prolonged preoxygenation.

In an ideal setting, a patient should breathe 100% oxygen for five minutes prior to attempts at intubation. In the ED, patients with impending apnea often will not tolerate a five-minute period of preoxygenation. Instead, eight vital capacity breaths of 100% oxygen may serve the same nitrogen washout function and effectively retard apnea-induced hemoglobin desaturation.[9] Most ED oxygen delivery devices do not deliver high concentrations of oxygen. Non-rebreather masks only achieve a 60-70% FiO_2 because they allow the entraining of room air.[10] When put to the test, some commonly used resuscitation bag-valve mask systems achieved FiO_2 levels that never exceeded 40%.[11]

The FiO_2 can be raised substantially by placing a nasal cannula set at 15 liters per minute (LPM) on the patient during the preoxygenation period. A full 15 LPM can be delivered effectively via a standard cannula.[12] Oxygen tubing can be hooked up to an oxygen tank under the ED cart or to a green adaptor connected to the flow meter on the wall. Be aware that at high-flow rates, a portable oxygen tank will empty quickly. A non-rebreather mask with a reservoir then is placed over the nasal cannula and set at the maximum possible setting. This means that the oxygen flow knob will be turned until it will not turn any farther. Keep staff from decreasing the oxygen flow rate since it is higher than they may be used to seeing in other situations. During the intubation procedure, the mask is removed but the nasal cannula is left in place. Passive oxygenation, also known as apneic oxygenation, provides real oxygen delivery to the patient and can help maintain saturations above 90% for an extended period of time.[12,13] If possible, patients should be positioned sitting up during preoxygenation, as patients will have less ventilation/perfusion mismatch in that position as compared to lying flat.

For patients who have altered mental status and are not able to tolerate preoxygenation, many providers would consider immediate intubation. However, recent descriptions of so-called "delayed sequence intubation" use ketamine or other sedation to calm the patient during preoxygenation without affecting the patient's respiratory drive.[14] Sedation may allow placement of a non-rebreather mask, noninvasive positive pressure ventilation, and/or a nasogastric tube for gastric decompression. These measures help prevent precipitous desaturation during intubation. It is important that the provider be prepared for intubation when initiating sedation, as some report apnea after giving ketamine or other sedation for preoxygenation.[15]

Position. Failure to position a patient properly prior to RSI is a common mistake. Time always should be taken to maximize all factors that can contribute

Table 2. Predictors of a Difficult Cricothyrotomy[7]

- Lack of operator skill and familiarity with the various techniques for cricothyrotomy
- Anatomical distortion of the anterior neck (trauma, infection, cancer, etc.) obscuring identification of the cricothyroid membrane
- Coagulopathy or excessive bleeding potential
- A small patient (younger than 10-12 years of age) in whom the cricothyroid membrane is too small to identify accurately
- Subcutaneous emphysema dissecting into the anterior neck obscuring the anatomy

Figure 1. Desaturation Curve

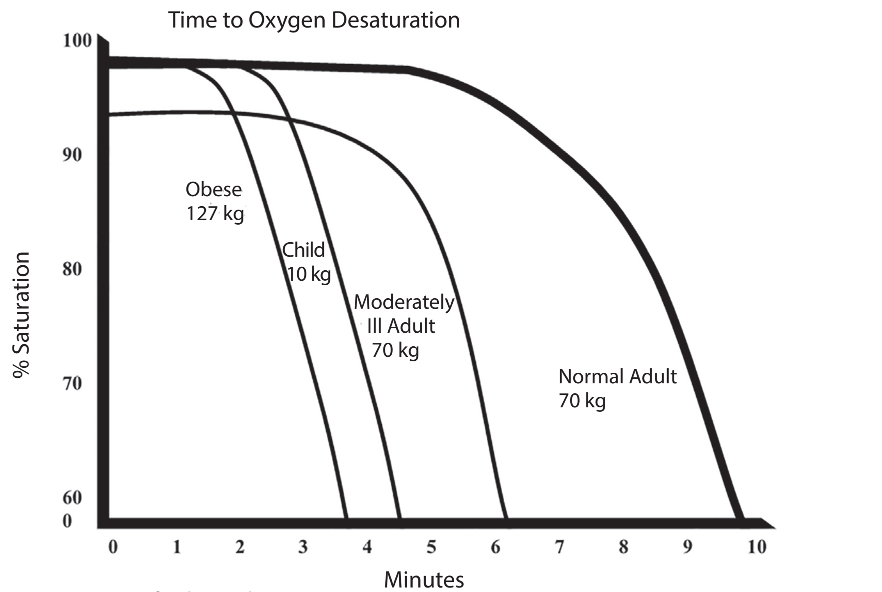


Figure courtesy of Colin Kaide, MD

to a successful intubation. Ideally, when possible, the earlobe is aligned with the sternal notch, with the neck extended and face parallel to the ceiling.[12] This maximizes the alignment of the oral axis, pharyngeal axis, and the glottis axis. In many cases, attention to the cervical spine is taken with a cervical collar in place. Manual in-line axial head and neck stabilization (MIAS) should be done with removal of either the anterior portion of the cervical collar or the entire cervical collar. MIAS has been shown to immobilize the cervical spine better in the setting of endotracheal intubation than the cervical collar alone.[16]

Pretreat. The pretreatment phase of RSI involves the delivery of medications to modify the physiologic sympathetic response during and after intubation. Current evidence lacks support for the routine use of pretreatment medications (lidocaine,[17] atropine,[18] and defasciculating agents[19]) in RSI, making pretreatment controversial and not routinely done. Older evidence suggested that fentanyl might be able to attenuate the rise in heart rate and blood pressure that often is seen during RSI.[20,21] Both laryngeal manipulation and the endotracheal placement of the endotracheal tube cause significant hemodynamic changes. This can be important when treating a patient who might not tolerate the hypertension or tachycardia associated with intubation.

Put to Sleep. The next step involves the induction of anesthesia with a rapid-acting induction agent. This step is performed virtually simultaneously with the administration of a paralytic agent. Because of the rapid onset of agents such as etomidate and ketamine, complete loss of consciousness can be achieved in 30 to 45 seconds. The onset of succinylcholine, often the paralytic agent of choice, is usually less than one minute. When the medications are given in rapid succession, the onset of induction and paralysis can be almost simultaneous. Cricoid pressure (Sellick's maneuver) no longer is recommended routinely. It has no proven benefits and potentially can make intubation more difficult.[22] Remember to avoid ventilating the patient until reoxygenation is required, as indicated by oxygen saturation falling below 90%.

Induction Agents. *Etomidate.* If only one induction agent were to be available to use for RSI in ED patients, etomidate would be the agent of choice. With its onset of action in one arm-brain circulation (30 seconds), a duration of action of only 6 to 10 minutes, and very little effect on cardiovascular hemodynamics, etomidate is ideally suited for sick, potentially hypotensive, or grossly unstable patients. It has reached the status of the go-to drug in ED RSI.[23] (*See Table 3.*)

Etomidate is a non-barbiturate, sedative-hypnotic agent unrelated to other induction agents. This medication typically is delivered by a single bolus dose of 0.3 mg/kg given by rapid IV push. The reported incidence of etomidate-induced myoclonus (up to 50-80%) is of little significance since all movement will be obliterated with the coadministration of a rapid-acting paralytic drug.[24]

Transient adrenocortical dysfunction lasting 12 hours occurs after a single bolus dose of 0.3 mg/kg of etomidate. This effect appears to have little clinical relevance, since serum cortisol levels remain within normal parameters during the period of dysfunction.[25]

If etomidate is given without a paralytic agent, most patients will continue to breathe. Although sufficient (though not optimal) intubating conditions often are produced with etomidate alone, myoclonus (especially involving the jaw) can interfere with the process, requiring rescue paralysis.

Even though etomidate normally is a cardio-stable drug and usually does not affect blood pressure significantly, in hypotensive patients the dose should be reduced to one-half the normal dose (0.15 mg/kg) to avoid further decreases in blood pressure.[26]

Table 3. Induction Agents

	Etomidate	Ketamine	Propofol
Dosage	IV 0.3 mg/kg IV 0.15 mg/kg in hypotensive patients	IV push 1 to 2 mg/kg	Adult and children: 2 to 2.5 mg/kg IV slowly over 30 sec in 2 to 3 divided doses
Pregnancy Category	C	Unknown but probably OK*	B
Preparation	2 mg/mL	100, 50, and 10 mg/mL	10 mg/mL
Description	Non-barbiturate, sedative hypnotic with anesthetic and amnestic properties (no analgesia)	Dissociative anesthetic; PCP derivative with anesthetic, amnestic, and analgesic properties	Non-barbiturate, sedative-hypnotic with anesthetic and amnestic properties
Onset and Duration	< 60 seconds; 6 to 10 minutes	30-60 seconds; 10-15 minutes	< 60 seconds; 5 to 10 minutes
Ideal Patient	• Need for rapid induction • Excellent for older patients or those with tenuous cardiovascular status • Hypotension	• The need for induction in a hypotensive patient • The need for induction in a patient with bronchospasm	• Induction of anesthesia in hemodynamically stable patients
Contraindications	• In Addison's disease, must supplement corticosteroids	• Elevated intracranial pressure (ICP) • Ischemic heart disease • Age < 3 months	• Allergy to albumin or egg whites • Hypotension • Compromised cardiac function • Caution in elderly patients (exaggerated hypotension)
Major Side Effects	• Apnea related to dose and rate of administration is rare and only minor respiratory depression is seen • Pain on injection common • Decreased ICP and cerebral perfusion pressure • Spontaneous myoclonus (not seizure) is seen in up to 30% of patients • Transient ACTH-resistant/hydrocortisone-responsive decrease in the production of cortisol • Vomiting and hiccups are possible during and post-procedure	• Transient 20-30% increase in BP and heart rate • Increase in ICP has been reported • Nystagmus • Nausea/vomiting is rare and usually occurs late after emergence • Excess salivation — use atropine/glycopyrrolate • Hallucinations on awakening (rare in children < 13 years); hallucinations are much less frequent than previously reported in adults and are virtually eliminated by the addition of 2 mg of midazolam • Transient apnea is very rare and seen only with rapid-push of high doses • Laryngospasm in patients with recent URI or history of severe asthma (not a significant concern when used with a paralytic agent)	• Transient hypotension and apnea are related to dose and rate of administration • Pain on injection (10%) • Decreased ICP and cerebral perfusion pressure

* Joel S, Joselyn A, Cherian VT, et al. Low-dose ketamine infusion for labor analgesia: A double -blind, randomized, placebo controlled clinical trial. *Saudi J Anaesth* 2014;8:6-10.

Ketamine. Ketamine, a dissociative anesthetic derived from phencyclidine (PCP), is unique in that it is the only agent that provides analgesic, amnestic, and anesthetic (sedative-hypnotic) properties.

Ketamine stimulates the release of endogenous epinephrine, causing an increase in heart rate, blood pressure, myocardial oxygen consumption, and bronchodilation.

This agent is suited best for hypotensive patients because of the cardiovascular support provided by this drug. Older recommendations often caution against the use of ketamine in patients with head injury. Although an increase in intracranial pressure is reported, this appears to result from an increase in cerebral blood flow. Increases in brain perfusion potentially can offset the increased intracranial pressure (ICP), calling into question the clinical relevance of this untoward effect.[27] Based on current evidence, head injury no longer is considered a contraindication for the use of ketamine.[28]

The frequency of emergence hallucinations reported with the use of ketamine in adults may be overstated. The addition of a benzodiazepine may control or minimize any effects that may occur. Further, in the ED patient who will remain ventilated, sedated, and paralyzed, emergence reactions have little significance.

Propofol. Propofol can produce potentially severe hypotension in cardiovascularly compromised or blood volume-depleted patients. Availability of other choices makes propofol suboptimal for ED RSI in all but the most hemodynamically stable patients.

Paralyze. This step involves giving the patient a rapid-acting paralytic agent. One technique that can simplify the process is to mix the induction agent and the paralytic agent in the same syringe. Etomidate is compatible with both succinylcholine and rocuronium and can be mixed. Likewise, ketamine can be mixed with either paralytic agent. The onset of action of both etomidate and ketamine is very fast and will take effect before the paralytic agents.

Paralytic agents induce profound muscle relaxation by inhibiting the action of acetylcholine (ACh) at the neuromuscular endplate. These drugs are either depolarizing or non-depolarizing, depending on their interaction with the ACh receptor.

Depolarizing agents such as succinylcholine fit into the ACh receptor and act initially to cause depolarization of the motor endplate and induce contraction, manifesting clinically as fasciculations. Subsequently, the receptor is blocked by the succinylcholine, preventing ACh from binding and producing further contraction. The paralysis lasts until succinylcholine is degraded by acetylcholinesterase.

Non-depolarizing agents, such as vecuronium and rocuronium, competitively inhibit the ACh receptor, occupying it and then exiting the site. These agents are removed from the neuromuscular junction and broken down in the liver. Their duration and onset of action generally are longer than succinylcholine.

Paralytic Agents. *Succinylcholine.* Succinylcholine is the first-line agent for paralysis in RSI. (*See Table 4.*) No agent has consistently demonstrated comparable rapidity of onset and short duration of action. In otherwise normal individuals, the use of succinylcholine results in only minimal changes in serum potassium of 0.5 to 1 mEq/L.[29,30] The magnitude of this effect is enhanced in two groups of patients. The first group is those who have had massive tissue destruction, such as severe burns older than 48 hours (can be used acutely, first 24 hours), massive trauma, and rhabdomyolysis. Because of the large surface area of damaged muscle that is capable of leaking potassium, severe, rapidly fatal hyperkalemia can develop. Mortality rates can reach 30% even with treatment.[31]

The second group is comprised of patients who develop an upregulation of ACh receptors. When muscles lose their normal input from motor nerves, the ACh receptors normally located in the motor endplates increase in density and spread over the surface of the muscle. Stimulation from succinylcholine causes an exaggerated release of potassium. Conditions that may cause this effect include central nervous system injury such as stroke, spinal cord injury, neuromuscular diseases with muscle wasting, disuse atrophy, and any other cause of chronic denervation.

The risk of adverse events when succinylcholine is used on known hyperkalemic patients ($K > 5.5$ mEq/L) is low, with a maximum catastrophic event risk of 7.9%.[30] Although this is not a trivial risk, succinylcholine still may be the drug of choice when neuromuscular paralysis is required and suitable alternatives are not available.

Succinylcholine can be stored unrefrigerated for up to three months with only minimal degradation (10% loss) of its paralytic properties.[32]

Rocuronium. Although rocuronium has the fastest onset of action of all the non-depolarizing agents, it is still slightly slower than succinylcholine in inducing paralysis. Its effects last significantly longer, however.

A meta-analysis reported that although rocuronium was inferior to succinylcholine in providing excellent intubating conditions, it was comparable to succinylcholine in inducing clinically acceptable intubating conditions.[33] Dosages of 1.2 mg/kg should be used to provide the closest approximation to succinylcholine. It is an effective alternative agent for RSI.

A new reversal agent for rocuronium, sugammadex, was approved by the FDA in 2015 for use in the operating room to speed recovery from paralysis. This molecule, which is a cyclodextrin with a lipophilic core and a hydrophobic outside, is able to encapsulate the rocuronium molecule, rendering it inactive.[34] Although it was specifically engineered to work on rocuronium, it does have some effect on vecuronium.

At this time sugammadex is not approved for ED use. Additionally, the ability of the drug to provide rescue in the "can't intubate, can't ventilate" scenario is questionable.[35] It may reverse the paralysis in three minutes, but that may not necessarily facilitate definitive management of the airway.

Vecuronium. Vecuronium also antagonizes the motor endplate acetylcholine receptors. This drug is not ideal for RSI but may be considered as a third-line agent if other agents are not available or are contraindicated.

Pass the Tube. Here, the endotracheal tube (ETT) is passed through the cords via direct visualization. A complete discussion of basic intubating techniques is beyond the scope of this article, so only a few tips will be presented. This discussion pertains to orotracheal intubation using direct laryngoscopy. A detailed discussion of video laryngoscopy and additional techniques for tube placement, including cricothyrotomy, will be discussed in a future issue.

Sweeping the tongue out of the way is a critical step in direct laryngoscopy. The intubator can insert the blade far to the right and force the tongue to the left side of the mouth. The tip of the laryngoscope must be deep enough into the mouth. Pressure placed too far forward on the tongue (instead of in the vallecula) will hinder the ability to lift the epiglottis. Failure to execute these maneuvers correctly are two common errors. To overcome this positioning problem, the laryngoscope blade should be placed as deep as possible into the oropharynx, allowing it to enter the esophagus. When the blade is withdrawn slowly, the first anatomical structure to be encountered is the larynx, followed by the epiglottis.

Another common method is Rich Levitan's approach to larygoscopy. Levitan emphasizes a methodic approach with careful suctioning to clearly identify the epiglottis — or "epiglottoscopy" — followed by blade placement into the vallecula.[42]

Table 4. Paralytic Agents

	Succinylcholine	Rocuronium	Vecuronium
Dosage	1.5 to 2 mg/kg IV rapid push	0.6 to 1.2 mg/kg IV rapid push 1.2 mg/kg is preferred dose	0.1 mg/kg IV rapid push
Pregnancy Category	C	B	C
Preparation	20 mg/mL	10 mg/mL	
Description	Depolarizing neuromuscular blocking agent	Non-depolarizing neuromuscular blocking agent	Non-depolarizing neuromuscular blocking agent
Onset	30 to 60 seconds	45 to 90 seconds	120 to 180 seconds
Duration	6 to 12 minutes	15 to 40 minutes	45 to 65 minutes
Reversal Agents	None	Neostigmine, sugammadex	Neostigmine, sugammedex
Ideal Patient	First-line paralytic agent in RSI	• Good first-line or second-line agent for RSI • Rapid onset (slower than succinylcholine) but long duration of action	• Possible third-line agent for RSI • Longer term paralysis, post RSI
Contraindications	• Burn or spinal cord injury patients > 48 hours post injury • Neuromuscular diseases • CVA less than 6 months out • Open-globe ocular injury • Use can cause bradycardia unless pretreatment with anticholinergic • Known hyperkalemia • Personal or family history of malignant hyperthermia	• Hypersensitivity to rocuronium • Hypersensitivity to bromides	• Hypersensitivity to vecuronium • Hypersensitivity to bromides
Major Side Effects	• Muscular fasciculation • Transient hyperkalemia • Increased ICP and intraocular pressure	• Tachycardia • Transient hypo/hypertension	• Tachycardia • Transient hypo/hypertension

If airway anatomy causes difficulty in finding the cords, visualization can be facilitated by moving the larynx into a more desirable position. By forcing the larynx to the right side of the intubating field, while simultaneously forcing the tongue to the left, the largest field of view can be obtained. Furthermore, by displacing the larynx backward (toward the table), an anterior larynx can be brought into a significantly better position placing it in the line of sight.

One technique that has been described to facilitate direct visualization of an anterior larynx is called "BURP" for backward-upward-rightward-pressure.[43,44] (*See Figure 2.*) The assistant (standing on the right side of the patient) applies pressure to the thyroid cartilage to displace it backward, toward the head and to the right (0.5 to 2 cm to the right and about 2 cm upward). Meanwhile, the intubator attempts to visualize the larynx. This technique can be useful during direct laryngoscopy and video-laryngoscopy. Alternatively, the intubator can place his or her hands over the assistant's hand and direct the pressure while attempting to visualize the glottis. When the cords are seen, the intubator can instruct the assistant to continue to hold the optimal position.

External laryngeal manipulation (ELM), also known as bimanual laryngoscopy, achieves the same backward, upward, and rightward airway repositioning as does BURP; however, the pressure is applied by the intubator with his or her right hand.[45,46] (*See Figure 2.*) This allows the intubator to visualize the effects of the manipulations and adjust the pressure accordingly. The final position of the larynx can be held by the assistant, freeing the intubator's right hand to complete the procedure. Comparing BURP to cricoid pressure to ELM found that ELM consistently provides the intubator with the best view of the cords.[47] In fact, the use of cricoid pressure can make intubation more difficult and has little proven benefit.[47]

Prove Placement

After intubation, the final step is to make sure the endotracheal tube actually is in the trachea. After the tube is passed and the cuff is inflated, the provider should auscultate the chest to listen for breath sounds. The stethoscope only needs to be placed in three locations to properly auscultate: the left axilla, the right axilla, and over the epigastrum. Unequal breath sounds can imply that the tube is in the right (or sometimes the left) mainstem bronchus. Physical exam alone is not sufficient to definitively confirm endotracheal tube placement into the trachea with

Table 5. RSI: Rocuronium vs. Succinylcholine

Succinylcholine

- Faster onset and shorter duration compared with other agents
- Creates "excellent intubating conditions" in an otherwise dynamic process[36]
- Historically the favored drug for RSI[36,37,38,39]
- No significant desaturations during intubations or incidence of failed intubations were demonstrated when comparing the two drugs[40]
- No significant difference in vocal cord injuries as an indirect measure of ease of intubation between them

Rocuronium

- Indicated in patients with known hyperkalemia and end-stage renal disease
- No significant desaturations during intubations or incidence of failed intubations were demonstrated when comparing the two drugs[40]
- No significant difference in vocal cord injuries as an indirect measure of ease of intubation between them[41]
- Sugammadex has evolved as a reversal agent for rocuronium, preventing binding of the drug to acetylcholine receptors within minutes. The intended use is to speed recovery in operating theaters, yet the potential in other areas, including emergency medicine (status epilepticus), may be promising. It is not currently approved for ED use.
- Fewer contraindications with rocuronium
- Caution in patients with liver disease
- Longer duration of action may be advantageous with progression through a difficult airway algorithm to cricothyrotomy without the need for re-dosing

Many clinicians are passionate about which paralytic agent is their go-to drug. Each drug has its advantages and disadvantages, and as long as the clinician is familiar with these, along with contraindications to succinylcholine, it probably doesn't matter which paralytic agent is used.

Figure 2. Laryngeal Repositioning

BURP

External laryngeal manipulation

External laryngeal manipulation with assistant
Photos courtesy of Colin Kaide, MD

a sensitivity of (94%) and specificity of (83%).[48] The American College of Emergency Physicians policy states that additional modalities should be used in conjunction with examination.[49]

The detection of end-tidal carbon dioxide ($ETCO_2$) is the most accurate way to evaluate endotracheal tube position, with sensitivities approaching 100% in patients who are perfusing adequately.[48] The sensitivity drops off significantly in patients in cardiac arrest or with severe disturbances in perfusion. Without perfusion to the lungs, CO_2 may not be detected despite the correct placement of the endotracheal tube in the trachea. There are two main methods of detecting $ETCO_2$: continuous quantitative waveform capnography and colorimetric devices.

The preferred method uses detection and quantitation of CO_2 displayed in a continuous waveform. Continuous capnography not only can detect correct endotracheal tube placement, but also can help with assessing the degree of resuscitation.

The use of inexpensive color-change CO_2 detectors represents a practical alternative. The detection of CO_2, indicated by a purple to yellow color change, is 100% specific for tracheal placement of the endotracheal tube, whereas the failure to detect color change strongly suggests esophageal intubation.[5] Some advocate ultrasound as another tool for confirmation of endotracheal tube placement.[50] Other devices, such as an esophageal intubation detection device, are available but lack evidence for widespread use.

Post-Intubation Management

There are three important issues to address after successful intubation: ventilator settings, sedation/analgesia, and continued paralysis.

Ventilator Settings. A detailed discussion of ventilator management is beyond the scope of this article, but a few basic points should be highlighted. A recent study in the *Annals of Emergency Medicine* on the effects of implementing early lung-protective ventilation found that it was associated with significant improvement in mechanical ventilation and in better clinical outcomes.[51] The following summarizes this lung-protective ventilation strategy.

• Tidal Volume (TV): The minimum TV that can keep the patient oxygenated and ventilated should be used. TV should be calculated using ideal body weight, as determined by the patient's height; 6-8 mL/kg should be used.

– Males: Ideal body weight = 50 kg + 2.3 kg for each inch over 5 feet.

– Females: Ideal body weight = 45.5 kg + 2.3 kg for each inch over 5 feet.

• Respiratory Rate: 20-30 breaths per minute.

• Positive end-expiratory pressure (PEEP): Start with an initial PEEP of ≥ 5 mmHg. PEEP can be increased if there is a need for increasing FiO_2.

– BMI > 30, set PEEP to 8 mmHg

– BMI > 40, set PEEP to 10 mmHg

• FiO_2: Begin to rapidly titrate the FiO_2 down to less than 60%, with a goal of decreasing it to 30-40% while keeping the O_2 sat between 90-95% or a PaO_2 of 55-60 mmHg.

• Plateau Pressures: Try to limit plateau pressures to < 30 mmHg.

• Head of Bed: Unless contraindicated, the head of the bed should be raised to > 30 degrees.

Post-Intubation Sedation/Analgesia. Post-intubation sedation/analgesia should be initiated as soon as possible after intubation. The duration of paralysis, particularly when using rocuronium, is much longer than the duration of the induction agent, leaving the patient potentially awake and fully paralyzed. Simply having an endotracheal tube in place is very uncomfortable. Some important points gleaned from the literature are as follows:

• A 2010 study published in the *Lancet* compared a protocol using adequate analgesia with morphine vs. morphine plus sedation with propofol followed by midazolam. The analgesia only group had fewer days on the ventilator.[52]

• A 2012 study in the *American Journal of Respiratory and Critical Care Medicine* showed that early deep sedation, the first four hours post-intubation, independently predicted a longer time until extubation was possible and an increase in mortality.[53]

• If a patient's pain can be controlled adequately, there may be no need for sedation. Sedation may be needed in cases in which agitation persists despite analgesia. Additionally, light sedation can improve ventilator synchrony and decrease overall work of breathing.[54]

• When a patient remains chemically paralyzed, a sedative agent with amnestic properties should be used.[54]

The overall conclusion suggested by the literature is that post-intubation, one should maximize pain control early using opioids and add in light sedation and titrate to the patient's response. Sedative and amnestic agents should be given during any period of chemical paralysis. One should avoid prolonged heavy sedation by adequately controlling the patient's pain.

Post-Intubation Paralysis. There is a time and a place for post-intubation chemical paralysis as long as amnestic and sedative agents are given concomitantly. Appropriate use of paralytics might include:

• the need to rapidly obtain imaging studies that require a patient to remain still;

• the patient who remains physically agitated despite pain control and sedation when the excessive physical activity may harm the patient or the treatment process;

• excessive fighting of the ventilator leading to breath stacking and elevated airway pressures.

The overall goal is to minimize the time the patient remains paralyzed and work to transition to adequate pain control and appropriate sedation.

Problem Solving. It is important to be able to trouble-shoot problems that can arise after intubation. One of the most concerning problems that can arise is sudden, progressive problems with ventilating the patient. A common clinical scenario might be a patient who is post-intubation with confirmed tracheal placement of the endotracheal tube who suddenly becomes hard to bag or is setting off ventilator alarms for increasing peak airway pressure, and then begins to desaturate. A quick and easy mnemonic to help remember the major causes of fixable problems is "DOPES."

• D: Dislodged endotracheal tube. During the process of securing the tube or moving the patient, the tube may come out of the trachea. Check end-tidal CO_2 using a color change device or preferably a continuous capnographic waveform to ensure endotracheal placement of the endotracheal tube. Revisualizing that the tube still is going through the cords also may be helpful.

• O: Obstruction. Placing a suction catheter down the endotracheal tube and suctioning secretions can help assure the tube is not blocked.

• P: Pneumothorax. Does the patient have a pneumothorax? Chest X-ray or real-time visualization of lung sliding on bedside ultrasound can quickly answer the question.

• E: Equipment Failure. Take the patient off the ventilator and bag the patient with a BVM on 100% FiO_2. This will eliminate the ventilator as the cause of the problem. Check for cuff leak.

• S: Stacked Breaths. Breath stacking creates autopeep. This happens in patients with asthma and COPD who do not completely exhale after each breath because of air trapping. Take the patient off the ventilator or BVM and allow the patient to exhale fully. The provider can assist the patient by slowly compressing the patient's chest, helping to force exhalation.

If these items are addressed and the patient still is difficult to ventilate, it makes it more likely that the patient has a lung problem, such as pulmonary edema or a large infiltrate.

Special Circumstances in RSI

Issues in the Hypotensive Patient

In the injured patient who is hypotensive and requires definitive airway management, some modifications to the standard RSI protocol should be considered. Although almost all induction agents can produce hypotension and myocardial depression, two agents — etomidate and ketamine — have the best hemodynamic profiles.[23,55] Etomidate has little effect on cardiac contractility and respiratory rate, making it an excellent choice for induction in the trauma or septic patient. Although etomidate is very "cardiostable" in hypotensive or volume-depleted patients, doses should be reduced to one-half the usual induction dose (from 0.3 mg/kg to 0.15 mg/kg).[26]

Table 6. Push-Dose Pressors[59]

- Epinephrine: Take a 10 mL saline flush syringe and squirt out 1 mL. Using this syringe, draw up 1 mL of epinephrine (100 mcg/mL). This is the epinephrine concentration ampule used in cardiac arrest. This will give you a 10 mcg/mL solution of epinephrine. Dose 0.5 to 2 mL every 2 to 5 minutes (5-20 mcg).

- Phenylephrine: Draw up one mL of phenylephrine from the 10 mg/mL vial. Inject this into a 100 mL bag of saline. This gives you a concentration of 100 mcg/mL. You can push doses of 0.5 to 2 mL every 2 to 5 minutes (50-200 mcg).

Ketamine releases endogenous catecholamines. In patients who are not catecholamine-depleted by prolonged maximal physiological stress, ketamine will accelerate heart rate and raise blood pressure.

Fortunately, the most commonly employed paralytic agent, succinylcholine, does not produce hypotension. If succinylcholine must be re-dosed in adults, atropine (1-2 mg IV) may be given prior to the second dose to prevent enhanced vagal tone.

In general, hypotensive patients should get the max dose of succinylcholine (2 mg/kg) and the minimum dose of etomidate (10 mg).

Another recognized problem that may develop during intubation of the hypotensive patient is depletion of catecholamines, or falling off the "catecholamine cliff," as some say. It occurs in patients who are undergoing significant periods of ongoing cardiovascular stress, such as worsening respiratory distress, severe congestive heart failure, and trauma with delayed resuscitation. When patients are suddenly paralyzed, intubated, and sedated, severe peri-intubation hypotension occurs. A crude, yet functional explanation may be depletion of central nervous system neurotransmitters and catecholamines that have been maintained by the underlying stress, which suddenly is abated by sedation and intubation. Patients in this category frequently succumb to a sudden peri-intubation cardiovascular collapse. There is a strong argument that can be made to provide these patients with catecholamine supplementation prior to and shortly after intubation once sedation has commenced.[56,57,58] This can be accomplished with peri-intubation pressors. Several techniques have previously been described to make "push-dose" pressors. Scott Weingart describes the method he uses. (*See Table 6.*)

The Trauma Airway

Closed Head Injury. In the closed head injured patient, changes in hemodynamics, oxygenation, and ventilation should be minimized in an attempt to maintain adequate cerebral perfusion pressure (CPP). CPP = MAP - ICP, where ICP is intracranial pressure and MAP is mean arterial pressure. MAP = [SBP + 2(DBP)]/3. Failing to manage a neurologically ill patient's airway could be devastating, with resultant secondary brain injury, respiratory arrest, aspiration pneumonitis, acute respiratory distress syndrome, and death.[60] Historically, blind nasotracheal intubation was the method of choice for securing the airway in the head-injured patient; however, orotracheal intubation with RSI now is standard and has been shown to be more rapid and associated with fewer complications.[61]

Laryngoscopy causes an increase in ICP via the reflex sympathetic response and direct laryngeal reflex. The goal during intubation is to minimize the two main contributors to increased ICP — patient positioning and hypoventilation. One must lower the head of the bed only briefly to intubate and return to 30 degrees following passage of the tube. Secondary monitoring with capnography assists with avoiding hypoventilation. As patients remain sedated, and sometimes paralyzed after intubation, obtaining a focused neurologic exam prior to intubation can help guide further post-intubation care, such as the need for early neurosurgical intervention.

Several measures are recommended in an effort to blunt the sympathetic response. Modifications in the standard RSI protocol should be performed as follows:

- Opiates (e.g., fentanyl) may be given two to three minutes prior to intubation to attenuate the sympathetic response in the normotensive patient.[20,21] Etomidate is an effective induction agent and has not been shown to increase ICP.
- Ketamine previously was contraindicated in patients with head injury; however, current data fail to show any deleterious effect from the use of ketamine in head-injured patients.[28] Owing to ketamine's increase in cerebral perfusion pressure and effects that counter systemic hypotension, it may be very useful in the head-injured patient.

In patients with significant blunt head trauma, cervical spine immobilization should be maintained, which can make ideal positioning of the head and airway more difficult. In contrast, gunshot wounds to the head impart an extremely small risk for cervical spine trauma, and immobilization rarely is needed.[62,63,64]

Maxillofacial Trauma. Facial trauma can distort normal anatomy significantly. Injuries can range in severity from soot in the airway from a house fire to a gunshot wound entering the submental area and exiting through the upper cranium. Any such scenario mandates special attention to the type and extent of injury and the current state of respiratory compromise.

In cases in which airway obstruction is either present or imminent, immediate decisive action is required. Alternatively, some patients initially present with minor respiratory difficulty but pose a significant risk for rapid deterioration (severe oral burns, gunshot wounds near the carotid, intraoral lacerations with hemorrhage). In these patients, a few moments should be taken to plan a strategy to intervene effectively and safely without causing more harm in the process. Expectant management or prolonging decision-making may force an emergent cricothyrotomy.

One of the most feared scenarios in airway management is the patient with maxillofacial trauma and an unsecured airway. As in the management of all difficult airways, proper preparation, including arrangements for backup plans, will increase the chances of successfully securing the airway significantly. The patient's neck immediately should be prepared for a surgical airway in the event of a failed intubation.

There is an associated cervical spine injury in up to 5% of patients with maxillofacial trauma, and neurologic injury in up to 36%.[64,65] However, the risk of cervical spine injury in patients with maxillofacial trauma is not any higher than the risk associated with other blunt trauma patients with a significant mechanism of injury.[66] LeFort III fracture frequently involves airway compromise secondary to soft tissue obstruction.

If there is no concern for cervical spine injury, place the patient in an upright or lateral position to allow blood and secretions to drain.[67] In preparing the patient for intubation, it is imperative to check the oropharyngeal anatomy. The patient's mouth should be opened to ensure adequate jaw mobility. This is particularly important in the setting of mandibular fractures because of the high incidence of temporomandibular joint dysfunction. RSI is the initial method of choice. If RSI is not possible or contraindicated, then a surgical airway is indicated.

Direct Airway Trauma. When discussing airway management in the setting of airway trauma, the two primary subcategories are penetrating and blunt trauma.

Patients with penetrating trauma often have several clinical clues to airway involvement. Important signs or symptoms of airway involvement include dyspnea, cyanosis, subcutaneous emphysema, hoarseness, and air bubbling through the wound site. Penetrating trauma to the neck carries a high degree of morbidity and mortality. The overall mortality is as high as 11%,[68] with up to 40% of patients requiring emergent intubation.[69,70] Zone I (between the clavicles and cricoid cartilage) is the least common site of neck injury but the most likely to require emergent airway management because of the close proximity of major pulmonary and vascular structures.[69]

Tracheobronchial injury occurs in approximately 10-20% of patients with penetrating trauma to the neck.[71,72] There are several important indications for intubation in the setting of penetrating trauma to the neck. They include acute respiratory distress, airway compromise from blood or secretions, extensive subcutaneous emphysema, tracheal shift, or altered mental status.[54,73] Any gunshot wound to the anterior neck is also an indication for early intubation to prevent obstruction from an expanding hematoma.[74] Finally, a stab wound to the anterior neck is an indication for early intubation only if there is evidence of vascular or direct airway trauma.[75]

Orotracheal intubation with RSI is the technique of choice in securing the airway in the patient with penetrating trauma to the neck.[74] Occasionally, administration of paralytics may turn a non-obstructed airway into an obstructed one because of relaxation of an injured airway segment. For this reason, it may be reasonable to do an "awake look" under sedation and topical anesthesia or an awake intubation. Ketamine is a good induction agent to use in this setting without paralytics.

In the setting of severely distorted anatomy or excessive secretions, if time allows, fiberoptic bronchoscopic intubation may be helpful to assess the degree of tissue injury. Occasionally, the entrance wound provides a direct communication between the anterior neck and the trachea. In this case, it may be easier to intubate directly through the wound. However, keep in mind that this is only a temporizing measure and ultimately must be converted to a more secure airway. If a surgical airway is required in the presence of an anterior neck hematoma, a tracheostomy should be performed rather than a cricothyroidotomy.

Blunt trauma to the neck frequently is more complicated. Unlike penetrating trauma, blunt trauma carries with it a very high incidence of associated cervical spine injuries. Specifically, up to 50% of blunt airway trauma patients have concurrent cervical spine injuries.[76] Therefore, strict cervical spine immobilization precautions need to be maintained while securing the airway. There also is a high incidence of esophageal injuries in patients with laryngotracheal fractures. For this reason, bronchoscopy and esophagoscopy are recommended in all patients with a high clinical suspicion for laryngotracheal injury.[67]

In terms of securing the airway, there are essentially three initial methods of choice: RSI, awake intubation, and awake fiberoptic intubation. The exception occurs in a laryngeal fracture, in which emergent tracheostomy is the best first maneuver. The American Society of Anesthesiology recommends awake intubation in all patients with possible airway anatomy disruption.[76] The concern is that the passage of the endotracheal tube may dislodge the severed ends of the larynx, turning a non-obstructed airway into an obstructed one.[67,69]

Cervical Spine Injury. All trauma patients who come in with cervical spine precautions should be assumed to have a cervical spine injury until proven otherwise. Because airway comes before cervical spine, airway management will be performed in the setting of a presumed cervical spine injury and appropriate precautions need to be taken when securing the airway. Keep in mind that 3-6% of initial survivors from major trauma have clinically significant cervical spine injuries.[77]

In uncomplicated trauma, a cervical spine may be clinically "cleared" and considered to have low probability of injury if the following five criteria are met: the absence of midline cervical spine tenderness, normal alertness, the absence of intoxication, painful distracting injury, and focal neurologic deficit.[77] Patients able to fulfill these criteria would seem unlikely to require airway support. Multitrauma scenarios in which airway management becomes mandatory often are significantly more complex, and by definition cannot employ the above criteria.

In gunshot wounds to the head (not involving the neck), the distinct absence of concomitant cervical trauma has been documented in multiple reports.[62,63,64] In this scenario, in the absence of other coexisting cervical injury (falls from significant height, etc.), the cervical spine may be considered as low priority.

The two initial methods of choice for securing the airway are oral intubation with RSI or awake fiberoptic intubation. When performing RSI, the anterior portion of the collar should be removed to allow for MIAS, which has been shown to immobilize the cervical spine better in the setting of endotracheal intubation than the cervical collar alone.[16] Consider airway adjuncts such as using video-assisted laryngoscopy to improve the chances of success while maintaining MIAS.

Thoracic Trauma. Thoracic trauma may present difficulties when it causes a distortion of the trachea from its normal midline position. This can occur with a tension pneumothorax or with a large intrathoracic hematoma. Occasionally, a large pneumothorax can cause significant subcutaneous emphysema tracking into the neck, which can interfere with the ability to identify the trachea and/or cricothyroid membrane.

Pneumothorax, hemothorax, or significant trauma to the lung (pulmonary contusion) can inhibit the ability to preoxygenate the patient adequately prior to the intubation. A pneumothorax should be treated prior to intubation. If the patient's airway can wait, it may be very reasonable to evacuate a hemothorax first to maximize the preoxygenation phase of the intubation.

Burns. The key principle in the treatment of burn patients with airway involvement is aggressive airway management. Because upper airway edema is progressive over 24 to 36 hours after the burn, it is advisable to secure an airway earlier rather than later. However, burn injuries develop over hours, so it often is reasonable to consult a burn specialist prior to securing an airway when appropriate. If there is prolonged transport to a burn center, consider a secure airway with intubation prior to transfer. Some indications for intubation are:

- stridor or hoarseness;
- known inhalation of toxic fumes;
- increased work of breathing;
- evidence of burns or edema of the posterior pharynx or glottic structures.

According to the National Fire Protection Association, smoke inhalation in burn patients accounts for nearly half of all deaths related to fire.[78] Further, the possibility of carbon monoxide and cyanide poisoning should be given consideration. Since a pulse oximeter is unable to differentiate between oxyhemoglobin and carboxyhemoglobin, a blood gas needs to be analyzed for carboxyhemoglobin. The sample can be either venous or arterial, as the CO level will be the same on both sides of the circulatory system.

Standard oral endotracheal intubation with RSI is the initial method of choice to secure the airway when no obvious obstruction is visualized. If in doubt, "an awake look" should be performed under sedation and topical anesthetics. If no problems are seen, one can proceed with RSI. However, because of the incidence of upper airway edema, there should be low threshold for moving on to fiberoptic intubation or cricothyrotomy. Carbonaceous sputum and soot in the mouth and nares are soft signs indicating for intubation. Although these findings should raise the index of suspicion for impending problems, alone they are not enough to warrant emergent intubation in a patient who does not manifest stridor, a hoarse voice, or other evidence of pharyngeal or laryngeal burns. The finding of smoke residue is not uncommon in burn victims, and superficial singed nasal hairs happen frequently without injury of deeper structures. One example is a flash burn secondary to ignited nasal cannula; rarely do these burns require intubation.[79] When in doubt, a nasopharyngoscope can be inserted to obtain a direct view of the cords to examine for burns or edema.

Conclusion

Airway management by the emergency physician has risen to a degree of sophistication well beyond that practiced by any other specialty, save anesthesia. It is the responsibility of any physician who practices emergency medicine to obtain and maintain the requisite skills necessary to practice airway management at this level.

At the core of airway management in all patients is a good understanding of when and how to intervene and provide definitive airway control. Although the setting and injury patterns can be dramatic, management of the trauma airway involves the same basic skills required for any other difficult airway. The well-prepared physician should possess sound, basic intubation skills and be intimately familiar with the various induction and paralytic agents. He or she should have a working knowledge of some of the common airway adjuncts and the requisite skills to create a surgical airway. Finally, the physician should be aware of and have a plan for the potential pitfalls and disasters that occur while taking control of a patient's vital functions.

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CME/CE Questions

1. A 100-kg man presents after a rollover motor vehicle crash. He is confused and combative. The decision is made to intubate him. His pulse is 130 with a BP of 70 systolic. Which drugs and dosages are best used for RSI in this situation?
   a. 30 mg etomidate/100 mg succinylcholine
   b. 100 mg propofol/200 mg succinylcholine
   c. 15 mg etomidate/200 mg succinylcholine
   d. 50 mg ketamine/100 mg rocuronium
2. Which of the following provides the optimal preoxygenation?
   a. Nasal cannula at 15 L/min + nonrebreather mask at 15 L/min
   b. Nasal cannula at 15 L/min
   c. Nonrebreather mask at 15 L/min
   d. Nasal cannula at 15 L/min + nonrebreather mask at maximum
3. Which of the following is considered the criterion standard for proving placement of an endotracheal tube?
   a. Fogging in the endotracheal tube
   b. Auscultation of bilateral breath sounds
   c. Detection of CO_2 by capnography
   d. Ultrasound
4. Which of the following statements is true?
   a. A gunshot wound to the head mandates cervical immobilization.
   b. Rocuronium is superior to succinylcholine for achieving paralysis during RSI.
   c. A cervical collar should be left in place during intubation to protect the cervical spine from excessive manipulation.
   d. The need for rescue cricothyrotomy appears to develop in fewer than 1% of intubations.
5. Which population of patients tends to experience desaturation the quickest?
   a. Obese patients
   b. Small children
   c. Moderately ill adults
   d. They all desaturate at very similar rates because the rate is dependent on the oxyhemoglobin dissociation curve, which is the same for all humans.

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