Chapter 29: Intubation and Mechanical Ventilation

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Content Update

Sugammadex was approved for use in the US in 2015. Details about benefits, risks, and dosage are provided at the end of the section entitled Rapid Sequence Intubation.

INTRODUCTION

The goals of emergency airway management are maintaining airway patency, assuring oxygenation and ventilation, and preventing aspiration. Tracheal intubation can achieve these goals. Sedation or paralysis after intubation can facilitate diagnostic testing. Extraglottic devices are discussed in detail in the chapter 28, "Noninvasive Airway Management."

Rapid-sequence intubation (RSI) is the sequential administration of an induction agent and neuromuscular blocking agent to facilitate endotracheal intubation. It is the method of choice for emergency airway management.[1] RSI allows the highest intubation success rate in properly selected emergency airway cases and is superior to sedation alone. Not all patients targeted for intubation are best managed with RSI; patients deeply comatose and those in cardiac or respiratory arrest will not likely have a response to laryngoscopy and may be intubated without pharmacologic assistance.

Whenever performing endotracheal intubation, anticipate airway difficulties and be facile with alternative airway techniques: bag-mask ventilation, rescue airway devices, and surgical access to the airway.[2] In addition, if bag-mask ventilation or rescue device deployment is not likely to succeed or if anatomic alterations exist that will not improve with RSI (edema, mass, bony disruption), do not extinguish intrinsic airway protection and respirations with paralysis.

Develop and discuss an intubation plan, and communicate responsibilities of the care team. Make sure medications are prepared. Have equipment for the difficult or failed airway available. Review proper patient positioning. Discuss the plan for postintubation hypoxia, hypotension, sedation, and ventilation. The use of a checklist may facilitate decision making and error prevention.[3]

OROTRACHEAL INTUBATION

PREPARATION

Clinical assessment, pulse oximetry, capnography, and the expected course of the patient all collectively guide decisions regarding the need for tracheal intubation. See the "Difficult Airway" section below for detailed discussion of airway assessment.

EQUIPMENT

Table 29–1 lists all equipment needed at the bedside before beginning intubation.

Table 29–1

Equipment Needed for Airway Management

Oxygen source and tubing
Ambu bag
Mask with valve, various sizes and shapes
Oropharyngeal airways—small, medium, large
Nasopharyngeal airways—small, medium, large
Suction catheter
Suction source
Pulse oximetry
Carbon dioxide detector
Endotracheal tubes—various sizes
Laryngoscope blades and handles
Syringes
Magill forceps
Stylets, assorted
Tongue blade
Intubating stylet (gum elastic bougie)
Water-soluble lubricant or anesthetic jelly
Alternative or rescue devices: video laryngoscopes, laryngeal mask airway, intubating laryngeal mask airway, Combitube® (Sheridan Catheter Corp., Argyle, NY), King LT® (King Systems, Noblesville, IN)
Surgical cricothyroidotomy kit
Medications for topical airway anesthesia, sedation, and rapid-sequence intubation

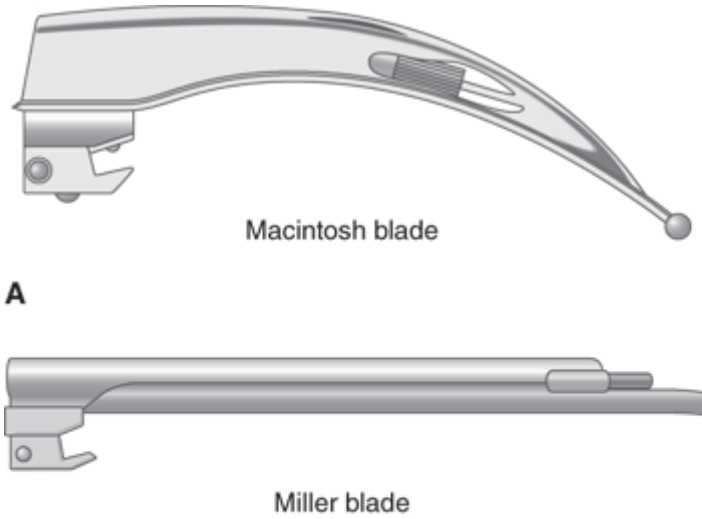
Rescue devices and a surgical airway option ideally are placed in a designated difficult airway cart in the ED and include pediatric sizes (see chapter 111, "Intubation and Ventilation in Infants and Children".)

When preparing for intubation, select the appropriate-size endotracheal tube (ETT) and an additional tube (0.5 to 1.0 mm smaller in diameter), and check the cuffs for air leaks with a 10-mL syringe. ETTs with high-volume, low-pressure cuffs are preferred. The approximate sizes for ETTs are 8.0- to 8.5-mm inner diameter for an average adult male and 7.5- to 8.0-mm inner diameter for an adult female. The second hole at the end of the tube above the bevel is called the **Murphy eye**. This hole permits some uninterrupted airflow if the tip is occluded. A stylet can aid emergent intubations, especially when using video laryngoscopy. Test the light on the laryngoscope after attaching the appropriate-size blade.

Laryngoscopes have straight or curved blades. The straight **Miller blade** physically lifts the epiglottis to visualize the larynx. The curved **Macintosh blade** tip is placed in the vallecula to indirectly lift the epiglottis off the larynx (Figure 29–1). The curved blade may cause less trauma and is less likely to stimulate an airway reflex when used properly, because it does not directly touch the larynx. It also allows more room for adequate visualization during tube placement and is helpful in the obese patient. The straight blade is mechanically easier to insert in many patients who do not have large central incisors. In adults, the curved Macintosh #3 is popular, and #4 is more useful in large patients. The straight Miller #2 and #3 are popular for the same purposes.

FIGURE 29–1.

A. Curved or Macintosh blade. B. Straight or Miller blade.



There are a variety of other straight and curved blades available; however, the Miller or Macintosh blades are most commonly used in direct laryngoscopy. Video laryngoscopes often use blades that have a much more acute angle to the blade because of the indirect visualization. **Video laryngoscopy** is an alternative to traditional direct laryngoscopy and preferred in some clinical scenarios including morbid obesity, difficult airway, or limited neck mobility.[4]

PROCEDURE

Preoxygenation

Begin preoxygenation as soon as possible, even for patients with no apparent hypoxia/hypoxemia. Preoxygenation optimizes blood oxygen content and also displaces nitrogen in the alveoli, creating a potential reservoir of oxygen that may prevent hypoxia and hypoxemia during the first minutes of apnea. Even with adequate preoxygenation, hypoxia develops more quickly in children, pregnant women, and obese patients and in hyperdynamic states. **To preoxygenate, administer 100% oxygen for 3 minutes, using a non-rebreather mask supplied with 15 L/min of oxygen. Nasal cannulas alone do not provide optimal preoxygenation**. Non-rebreather masks typically deliver 60% to 70% oxygen. A bag-mask ventilator, appropriately applied, can deliver 90% to 97% oxygen. This requires a tight seal, with either active bagging or enough inspiratory pressure from the patient to open the one-way valve. There are a number of bag-mask devices that vary in their oxygen delivery; use a bag-valve mask device with one-way inspiratory and expiratory valves.

In patients who have arterial oxygen saturations that remain below 95% despite supplemental oxygen, a short period of noninvasive positive-pressure ventilation may improve the oxygen reservoir. This strategy is particularly effective in obese patients.[5] Elevating the head of the patient 20 to 30 degrees improves preoxygenation. Finally, providing high-flow nasal cannula oxygen (≥15 L/min) or the Optiflow™ oxygen delivery system (which allows even higher flow) throughout the apneic phase of RSI prolongs the period of safe apnea during paralysis and is wise in all patients undergoing emergent RSI.[5]

Patient Positioning

Flex the lower neck and extend the atlanto-occipital joint (sniffing position) to align the oropharyngeal–laryngeal axis for a direct view of the larynx. Padding under the shoulders, not the neck, also improves visualization. For most airway maneuvers, the best position occurs when **the ear is horizontally aligned with the sternal notch**. Inadequate equipment preparation and poor patient positioning are common failure triggers; take the time to do these right before using the laryngoscope. Reposition the patient if initial attempts at viewing the larynx fail.

Sellick Maneuver

The **Sellick or cricoid maneuver** (application of direct pressure on the cricoid ring in the unconscious or paralyzed patient) can impair bag-mask ventilation, worsen the laryngoscopic view, and hamper insertion of the tube.[6] Some practitioners still use it to prevent aspiration of gastric contents, although it may trigger vomiting. If the Sellick maneuver is used, apply *cricoid* (not thyroid) pressure and release if visualization does not improve. Aspiration occurs due to low esophageal sphincter tone, depressed protective laryngeal airway reflexes, or stimulation in the patient with upper airway fluids or stomach contents (Table 29–2).

Table 29–2

Common Situations and Conditions Associated with Aspiration

Iatrogenic
Bag-valve mask ventilation
Nasogastric tube placement
Pharmacologic neuromuscular paralysis
Medical conditions
Trauma
Bowel obstruction
Obesity
Overdose
Pregnancy
Hiatus hernia
Seizures

Endotracheal Tube Insertion with Direct Laryngoscopy

Instructions for ETT insertion are summarized in Table 29–3.

Table 29–3

Instructions for Endotracheal Tube Insertion

Step	Comments
1. Hold laryngoscope in left hand.	Holding the laryngoscope at the base, where the blade inserts to the handle, aids proper use and lift; do not hold further up the handle.
2. Use right hand to:	Remove dentures and any obscuring blood, secretions, or vomitus suctioned before insertion of the ETT.
Insert the ETT	Use a properly sized, semi-rigid, malleable, blunt-tipped, metal or plastic stylet to assist with tube placement. The tip of the stylet must not extend beyond the end of the ETT or exit the Murphy eye.
Operate suction catheter.	
Manipulate larynx externally to enhance the visualization.	
3. Insert blade into the right corner of the patient's mouth.	The flange of the curved Macintosh blade will push the tongue toward the left side of the oropharynx.
	If the blade is inserted directly down the middle, the tongue can force the line of sight posteriorly, impairing the view.
4. Visualize arytenoids.	—
5. Lift epiglottis.	Lift the epiglottis directly with the straight blade or indirectly with the curved blade.
6. Expose larynx.	Pull laryngoscope handle in the direction that it points (i.e., 90 degrees to the blade).
	Cocking the handle back, especially with the straight blade, risks fracturing central incisors and is ineffective at revealing the cords.

Step	Comments
7. Advance blade incrementally.	Look for the arytenoid cartilages to avoid overly deep insertion of the blade, which is a common error. BURP maneuver may improve visualization.
8. Advance ETT.	Visualize tube *and* cuff passing through vocal cords.
	Correct tube placement is a minimum of 2 cm above the carina (approximately 23 cm in men and 21 cm in women).
	The base of the pilot tube (a tube with the adapter to inflate the cuff) is usually at the level of the teeth.
9. Check ETT placement.	Listen for bilateral breath sounds and the absence of epigastric sounds.
	Confirm placement with colorimetric carbon dioxide detector or capnography.
10. Inflate balloon.	Use 5–7 cc of air. Ask the technician to check cuff pressure to avoid tracheal injury from pressure (target 25–40 cm H_2O).
11. Secure ETT.	Do not impede cervical venous return with umbilical tape or a fixator; circumferential securing devices can cause skin breakdown if too tight or in place too long.
	Use a modified clove-hitch knot or a commercial fixator to avoid kinking the pilot tube.

Abbreviations: BURP = backward-upward-rightward pressure; ETT = endotracheal tube.

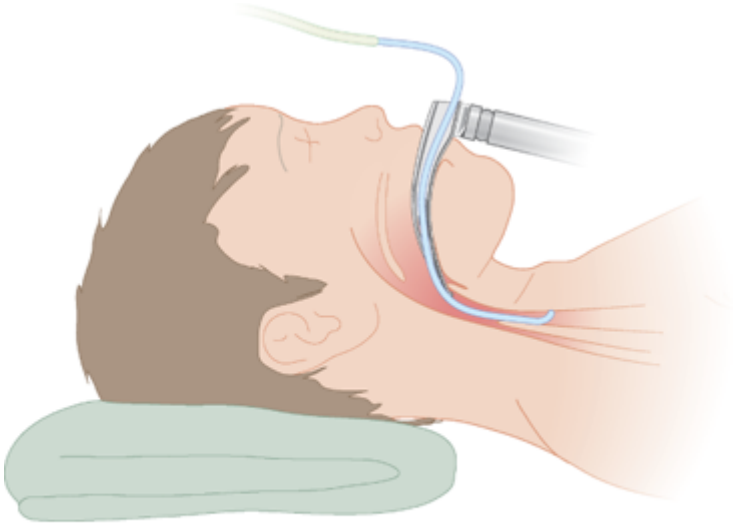
Suction at the bedside is critical. The Yankauer catheter is the most common device used, but any large-diameter suction system and tubing that allows for the removal of particulate matter or large clots is acceptable.

ETT insertion without clear cord visualization commonly leads to espohageal placement. Some techniques can help avoid esophageal placement. (1) retracting the right side of the mouth laterally by an assistant aids visualization; (2) using backward-upward-rightward pressure on

the thyroid cartilage enhances visualization of the anterior glottis (**BURP maneuver**); and (3) bimanual laryngoscopy, where the intubator manipulates the larynx with the right hand until ideal visualization and then an assistant maintains this position, improves visualization of the vocal cords.[6] To avoid error, make sure you see the cuff of the ETT pass completely through the cords. Finally, abort the attempt if you cannot visualize the larynx.

The endotracheal introducer, also known as the "**gum elastic bougie**"[7] (Figure 29–2), may aid and is typically 70 cm in length and made of plastic. The angled tip facilitates insertion when the glottis cannot be fully visualized, although it is not helpful when no visualization exists. Once correctly inserted, you may feel the bougie tip moving over the tracheal rings. Thread the ETT over the introducer into the trachea and then remove the introducer. Never force the tube through the vocal cords, which can avulse the arytenoid cartilages or lacerate the vocal cords.

FIGURE 29–2.
Depiction of a gum elastic bougie. Note the angled tip.



Most difficulties in passing the tube are a result of the failure to maintain the best possible laryngoscopic view, selecting too large a tube, applying cricoid pressure, or the formation of an undesirable curve on a semi-rigid stylet that is inserted into the ETT. A stylet angle of <35 degrees is more likely to pass through the glottis. Switching to a smaller tube, altering the curve of the stylet, or rotating the tube 90 degrees to align the bevel with the glottic opening are other techniques for eventual success. Do not apply cricoid pressure when inserting the ETT.

Advance the tube until the cuff disappears below the cords. Inflate the cuff with 5 to 7 cc of air. To avoid ischemia of the tracheal mucosa while limiting aspiration and maintaining a seal, target a cuff pressure of 25 to 40 cm H_2O. There is poor correlation between volume of air and tracheal cuff pressure, and if there is concern about cuff pressure, a manometer can be used to measure cuff pressure.

Tracheobronchial Suction

After ETT insertion, use a well-lubricated, soft, curved-tip catheter to suction the tracheobronchial tree. Straight catheters usually will pass into the right mainstem bronchus. If a curved-tip catheter is available, turn the head to the right and rotate the catheter to facilitate passage into the left bronchus. The suction catheter should be no larger than half the diameter of the ETT to prevent pulmonic collapse from insufficient ventilation during suctioning. Insert the catheter without suctioning and then slowly remove it while rotating and suctioning over 10 to 15 seconds.

Complications of suctioning include hypoxia/hypoxemia, cardiac dysrhythmias, hypotension, pulmonic collapse, and direct mucosal injury. Intracranial pressure may increase during suctioning due to coughing.

Confirm Endotracheal Tube Location

"When in doubt, take it out."

Mainstem bronchial or esophageal intubation results in hypoxia or hypoxemia and hypercarbia. There is no clinically reliable substitute for directly visualizing the tube passing through the vocal cords. Other clinical assessments, including chest and epigastric auscultation, tube condensation, or symmetric chest wall expansion, are not infallible. "Breath sounds" from the stomach can be transmitted through the chest after gastric insufflation. You should confirm intratracheal tube positioning with an objective measure.

The two basic categories of confirmatory adjuncts either assess expired (end-tidal) carbon dioxide ($ETCO_2$) or assess misplacement by esophageal detection. Both have advantages provided that the operator knows the limits of each approach.

Capnometers and capnographs measure carbon dioxide in the expired air. The most commonly used capnometric devices in the ED are colorimetric, with a pH-sensitive purple filter paper. Hydrogen ions are formed by contact with carbon dioxide, resulting in color changes that vary with the concentration of carbon dioxide. For example, with the Nellcor Easy Cap II (Nellcor, Boulder, CO), the paper turns yellow after exposure to 2% to 5% $ETCO_2$, which is equivalent to 15 to 38 mm Hg partial pressure of carbon dioxide (Pco_2). No color change occurs (the filter

paper remains purple) if the $ETCO_2$ is <0.5%, equivalent to <4 mm Hg Pco_2. Colorimetric capnometers are useful for assessing proper ETT placement but are not accurate enough for precise $ETCO_2$ determinations and cannot exclude bronchial mainstem intubation.

Capnography displays real-time characteristic carbon dioxide waveforms. A persistent positive capnograph formation after clear and direct visualization of tube placement approaches certainty about tube placement. Rarely, a misplaced hypopharyngeal glottic tube tip may result in normal oximetry and capnography in a spontaneously breathing patient. This error is recognized by noting inadequate depth of tube insertion, inadequate ventilatory volumes, or incorrect tube placement on chest x-ray.

Table 29–4 notes conditions associated with false colorimetric or capnographic carbon dioxide readings.

Table 29–4

Conditions Associated with False Colorimetric or False Capnographic Carbon Dioxide Readings

False-Negative Reading	**Comments**
Low pulmonary perfusion—cardiac arrest, inadequate chest compressions during CPR, massive pulmonary embolism	—
Massive obesity	—
Tube obstruction	Secretions, blood, foreign bodies
False-Positive Reading	**Comments**
Recent ingestion of carbonated beverage	Will not persist beyond 6 breaths
Heated humidifier, nebulizer, or endotracheal epinephrine	Transient

Esophageal detection devices help determine initial tube location and do not depend on adequate cardiac output and pulmonary perfusion—an asset in the cardiac arrest patient. When the ETT is in the esophagus, the soft, noncartilaginous walls will collapse, and air cannot be easily aspirated with an esophageal detector. Esophageal detection devices use a syringe aspiration or a compressible bulb technique. The device is attached to the ETT adapter after intubation but before ventilation. The syringe is then rapidly retracted or the bulb is compressed. Taking advantage of the anatomic differences between the rigid cartilage of the trachea and the collapsible esophagus, syringe aspiration or bulb refilling is rapid when in the trachea. If the ETT tube is in the esophagus, the vacuum causes the esophagus to collapse around the tube, creating resistance to aspiration or preventing the bulb from refilling.

After intubation, obtain a chest x-ray to identify mainstem bronchus intubation and to locate the ETT tip. A chest x-ray does not reliably distinguish ETT placement in the trachea from the esophagus.

COMPLICATIONS OF ENDOTRACHEAL INTUBATION

Adverse events include unrecognized esophageal intubation, aspiration, oxygen desaturation, hypotension, dysrhythmia, and cardiac arrest. In the ED, first-attempt success is achieved 80% to 95% of the time.[1,8,9] Higher first-attempt success is associated with more experienced clinicians, trained emergency physicians, the use of RSI, the use of video laryngoscopy, and the absence of predictors of airway difficulty.[4,10] Multiple intubation attempts are associated with increased adverse events; this is why it is important to employ an intubation strategy most likely to lead to first-pass success.[9,11]

Immediate complications include unrecognized esophageal intubation or mainstem bronchus intubation. *Never assume correct positioning and patency after intubation if deterioration is seen*. **Tube displacement can occur during patient movement or if the tube is not properly secured**. Repeated suctioning helps prevent secretions from obstructing the tube or bronchus. Cuff displacement or overinflation obstructs or damages the airway. If tracheal ball-valve obstruction is suspected, deflate the cuff.

If the **ETT cuff leaks** after the intubation, check the inflation valve. A simple remedy for a leaking inflation valve is to attach a three-way stopcock to the valve, re-inflate the cuff, and turn off the stopcock. If the tube needs to be replaced, use a tube changer. Commercially available tube changers are semi-rigid catheters with 15-mm adaptors or connectors to permit ventilation during the tube exchange. Insert the changer into the ETT, withdraw the ETT, and then insert a new ETT over the catheter and reconfirm placement.

Although uncommon, soft tissue injury related to emergent endotracheal intubation does occur. Arytenoid cartilage avulsion or displacement, usually on the right, will prevent the patient from phonating properly after extubation. Other complications include intubation of the pyriform

sinus, pharyngeal-esophageal perforation, and development of stenosis. Subglottic stenosis usually occurs in patients with poorly secured tubes who are combative or mechanically ventilated for extended intervals.

RAPID-SEQUENCE INTUBATION

RSI is the simultaneous administration of an induction and a neuromuscular blocking agent to facilitate tracheal intubation and is preferred for emergency intubation (Table 29–5).

Table 29–5

Rapid-Sequence Intubation Steps

1. Set up IV access, cardiac monitor, oximetry, and capnography/capnometry.
2. Plan procedure incorporating assessment of physiologic status and airway difficulty.
3. Prepare equipment, suction, and potential rescue devices.
4. Preoxygenate and denitrogenate.
5. Consider pretreatment agents based on underlying conditions.*
6. Induce with sedative agent.
7. Give neuromuscular blocking agent immediately after induction.
8. Bag-mask ventilate only if hypoxic; otherwise, provide high flow oxygen during apneic phase. Cricoid pressure during laryngoscopy only, if needed.
9. Intubate trachea after muscle relaxation has been achieved.
10. Confirm placement and secure tube.
11. Provide postintubation sedation and low tidal volume (6 cc/kg start) management.

*It is unclear if pretreatment improves outcome.[12]

Bag-mask ventilation may increase gastric distention and is best deferred in the well-oxygenated patient before laryngoscopy. Once the patient is adequately sedated and paralyzed, perform laryngoscopy and tracheal intubation. Contraindications to RSI are relative and primarily occur when t[illegible]est that paralysis may lead to a "cannot intubate, cannot ventilate" predicament or when not needed or

unlikely to aid (massive edema or fixed anatomic hindrances). Always be prepared for failure and have two alternatives ready, often including rescue airways.

PRETREATMENT AGENTS

Pretreatment agents attenuate adverse physiologic responses to laryngoscopy and intubation; however, data do not show a clear outcome benefit from pretreatment agents.[12,13] Adverse effects from laryngoscopy include a reflex sympathetic response that causes increases in heart rate and blood pressure; this may be harmful in patients with elevated intracranial pressure, myocardial ischemia, and aortic dissection. In children, the vagal response predominates and can result in bradycardia, even in the absence of succinylcholine. Patients without cerebral autoregulation can experience a centrally mediated increase in intracranial pressure. Laryngeal stimulation also can have respiratory effects, including laryngospasm, cough, and bronchospasm. Constraints on time, usually from worsening clinical status, often preclude pretreatment; if pretreatment agents are used, administer them 3 to 5 minutes before initiation of RSI (Table 29–6). Finally, the duration and nimbleness of laryngoscopy are the biggest factors in physiologic perturbations; quick and with minimal extraneous movement are best.

Table 29–6

Pretreatment Agents Considered in Rapid-Sequence Intubation

Agent	Dose	Indications	Precautions
Lidocaine	1.5 milligrams/kg IV/topically	Elevated ICP	Lack of evidence-based studies on effectiveness in ICP[12]
		Bronchospasm	No evidence of improved outcome and may not be better than inhaled albuterol
		Asthma	
Fentanyl	3 micrograms/kg IV	Elevated ICP	Respiratory depression
		Cardiac ischemia	Hypotension
		Aortic dissection	Chest wall rigidity
Atropine	0.02 milligram/kg IV	Children <5 y with bradycardia	Minimal dose 0.10 milligram
		Children <10 y receiving succinylcholine and with bradycardia	Recommend giving in response to bradycardia, not as routine agent[13]
	0.01 milligram/kg IV	Bradycardia from repeat succinylcholine in adults	

Abbreviation: ICP = intracranial pressure.

Fentanyl can attenuate the reflex sympathetic response to airway manipulation. It may aid in patients in whom a rise in blood pressure and heart rate could be detrimental, such as patients with elevated intracranial pressure and certain cardiovascular conditions (i.e., aortic dissection, i[Loading [Contrib]/a11y/accessibility-menu.js]). Fentanyl is less likely to produce hypotension in the suggested dose (3 micrograms/kg IV) than other

agents with similar effects and has a rapid onset of action. Adverse reactions, such as respiratory depression and chest rigidity, are rare when fentanyl is given in lower RSI doses (3 micrograms/kg IV) and over 30 to 60 seconds.

Pretreatment with atropine limits but does not universally prevent bradycardia in children. It is recommended for symptomatic bradycardia, and not as a routine agent.[13] **Pretreatment with a small dose of a nondepolarizing neuromuscular blocking agent, such as vecuronium or rocuronium in one tenth of full dose, is no longer recommended to alter side effects**.

INDUCTION AGENTS

There is no single agent of choice for achieving adequate sedation during RSI in the ED. All of the commonly used agents offer advantages and risks in specific clinical conditions (**Table 29–7**).

Table 29–7

Preferred Rapid-Sequence Intubation Induction Agents

Agent	Dose	Onset	Duration	Benefits	Caveats
Etomidate	0.3–0.5 milligram/kg IV	<1 min	10–20 min	↓ ICP	Myoclonic jerking or seizures and vomiting in awake patients
				↓ Intraocular pressure	No analgesia
				Neutral BP	↓ Cortisol
Propofol	0.5–1.5 milligrams/kg IV	20–40 s	8–15 min	Antiemetic	Apnea
				Anticonvulsant	↓ BP
				↓ ICP	No analgesia
Ketamine	1–2 milligrams/kg IV	1 min	10–20 min	Bronchodilator	↑ Secretions
				"Dissociative" amnesia	↑ BP
				Analgesia	Emergence phenomenon

Abbreviations: BP = blood pressure; ICP = intracranial pressure.

Etomidate

Etomidate, a nonbarbiturate hypnotic, is a popular agent for ED RSI. It protects from myocardial and cerebral ischemia, causes minimal histamine release, has little hemodynamic depression in most patients, and has short duration of action. Myoclonus, nausea, and vomiting can occur in awake patients, but clinically important effects are rare. Etomidate is not an analgesic, and it does not blunt the sympathetic response to intubation. There is no evidence that a single dose of etomidate given in the ED for RSI worsens patient outcomes through cortisol inhibition, even in septic shock, although this can be measured and is key to recognize after use.[14]

Propofol

Propofol is a highly lipophilic, rapid-acting sedative that is effective for emergent RSI. Propofol has a more rapid onset of action than etomidate and a shorter duration of action. It has anticonvulsant and antiemetic properties, and it may lower intracranial pressure without triggering histamine release. Propofol can cause hypotension through myocardial depression and vasodilation; for this reason, avoid it in trauma patients and any patient with hypovolemia or hypotension. Trismus and dystonic reactions are rare side effects of propofol.

Ketamine

Ketamine, a phencyclidine derivative, is a dissociative induction agent that provides analgesia and amnesia. Ketamine preserves the respiratory drive, an ideal feature for sedation during awake intubation. It causes an increase in blood pressure and heart rate through catecholamine release, which is useful in hypovolemic or hypotensive patients. Ketamine causes direct smooth muscle relaxation and bronchodilation and is often used in those with refractory status asthmaticus.

Ketamine does not cause consistent increased intracranial pressure in sedated and ventilated patients, and some studies suggest that the drug has possible cerebroprotective effects.[15] Despite previous theoretic concerns about γ-aminobutyric acid–altering effects that could worsen CNS function, ketamine is a good option in patients with head injury and hypotension. Ketamine is not a preferred agent for the elderly or for patients with a potential for cardiac ischemia, because of the potential for associated tachycardia and hypertension.

Other Agents

Barbiturates commonly cause hypotension from myocardial depression and venous dilatation; they have been largely replaced with etomidate or propofol. Benzodiazepines may be used when other agents are contraindicated or unavailable, with **midazolam** being the common choice.

PARALYTIC AGENTS

Depolarizing and nondepolarizing neuromuscular blocking agents facilitate RSI (**Table 29–8**). Depolarizing neuromuscular blocking agents have high affinity for cholinergic receptors of the motor end plate and are resistant to acetylcholinesterase. Depolarizing blockade is not antagonized and may be enhanced by anticholinesterase agents. Succinylcholine is the common depolarizing agent.

Table 29–8

Succinylcholine Complications and Contraindications

Clinically important hyperkalemia in patients with:
Burns >5 d old
Denervation injury >5 d old
Significant crush injuries >5 d old
Severe infection >5 d old
Preexisting myopathies
Preexisting hyperkalemia
Fasciculations
Transient increased intragastric, intraocular, and intracranial pressure (? impact)
Masseter spasm alone or with malignant hyperthermia
Bradycardia
Prolonged apnea with pseudocholinesterase deficiency or myasthenia gravis

Nondepolarizing neuromuscular blocking agents compete with acetylcholine for the cholinergic receptors and usually can be antagonized by anticholinesterase agents. **Rocuronium** and **vecuronium** are nondepolarizing agents used in the emergency setting; rocuronium is the most common alternative to succinylcholine in RSI due to its shorter duration of action and its ability to achieve intubating conditions closest to those of succinylcholine (**Table 29–9**).[16] Vecuronium has a longer time of onset, even with the high-dose approaches, making it a less favorable choice in RSI; it is primarily used for ongoing paralysis after intubation.

Table 29–9

Paralytic Agents in RSI

Agent	Adult Intubating IV Dose	Onset	Duration	Comments
Rocuronium (intermediate/long)	1 milligram/kg	1–3 min	30–45 min	Tachycardia. Longer duration of action and onset compared to succinylcholine. Most common alternative to succinylcholine in RSI.[15]
Vecuronium (intermediate/long)	0.08–0.15 milligram/kg	2–4 min	25–40 min	Prolonged recovery time in obese or elderly, or if there is hepatorenal dysfunction.
	0.15–0.28 milligram/kg (high-dose protocol)		60–120 min	
Succinylcholine	1.5 milligrams/kg	45–60 s	5–9 min	Provides optimal intubating conditions most quickly. There are several rare but important contraindications (see Table 29–8).

In the ED, neuromuscular blockade can facilitate tracheal intubation, improve mechanical ventilation, and help control intracranial hypertension. Paralysis improves oxygenation and decreases peak airway pressures in a variety of disorders, including refractory pulmonary edema and respiratory distress syndrome. Neuromuscular blockade limits assessments of neurologic status, and long-term use increases critical illness polyneuropathy and posttraumatic stress disorder. Neuromuscular blockers are neither anxiolytics nor analgesics, so agents targeting these are needed. **Maintain sedation during initial paralysis to avoid patient awareness;** later, some patients can be managed with less or little sedation, but this is not ideal in the emergent setting.

Depolarizing Agent: Succinylcholine

Succinylcholine is the most commonly used agent for neuromuscular blockade in ED RSI. Succinylcholine is two joined acetylcholine molecules and is rapidly hydrolyzed by plasma cholinesterase. It has a rapid onset after IV dosing and a shorter duration of action than do the r Loading [Contrib]/a11y/accessibility-menu.js iculation, complete relaxation occurs at 60 seconds, with maximal paralysis at 2 to 3 minutes.[17] Effective

respirations resume in 8 to 12 minutes. IM succinylcholine (4 milligrams/kg) will act more slowly and last longer; however, this is best reserved for the rare setting where paralysis is required absent IV access.

Succinylcholine provides excellent intubation conditions and is the preferred agent for RSI in the ED.[16] In the event of a failed airway, mask ventilation may be required for up to 12 minutes, until the return of spontaneous ventilation. Give the induction agent immediately before succinylcholine to avoid awareness and enhance intubating conditions.

Serum potassium will transiently rise an average of 0.5 mEq/L with succinylcholine, usually without any clinical impact (Table 29–9). A clinically significant or exaggerated hyperkalemic response can occur 5 or more days after a burn, denervation, or crush injury. The exaggerated hyperkalemic response is due to acetylcholine receptor upregulation at the neuromuscular junction, which requires time to occur and thus is not an immediate factor. Patients with preexisting myopathies are at particular risk for a life-threatening hyperkalemic response. **Do not use succinylcholine in patients with suspected preexisting significant hyperkalemia (especially renal failure), myopathies, or myasthenia gravis**.

Other succinylcholine complications are rare. Genetically susceptible individuals may develop malignant hyperthermia after succinylcholine (or after a volatile inhaled anesthetic). Suspect malignant hyperthermia if unexplained rapid fever with muscle rigidity, acidosis, or hyperkalemia occurs after succinylcholine, and treat with IV dantrolene sodium (2.5 milligrams/kg) and temperature control. Patients with acquired or genetic atypical or low plasma cholinesterase may have prolonged paralysis. Cocaine is metabolized by plasma cholinesterase, which reduces the amount of enzyme available for succinylcholine metabolism. **If known plasma cholinesterase deficiency is suspected, use a nondepolarizing agent (usually rocuronium) instead of succinylcholine**.

Nondepolarizing Agents

Rocuronium is an intermediate-duration nondepolarizing agent that is an excellent alternative to succinylcholine for RSI.[16] By increasing the dose of rocuronium to 0.9 to 1.2 milligrams/kg, the onset of action approximates that of succinylcholine, but the duration of action is prolonged. There are fewer side effects and contraindications with rocuronium than with vecuronium (Table 29–8).

Vecuronium bromide is an intermediate- to long-acting nondepolarizing agent (Table 29–8). Vecuronium has no cardiac effects. Hypersensitivity reactions are rare, doses are only minimally cumulative, and excretion is biliary. Despite the lack of histamine release, hypotension may occur through other mechanisms that include sympathetic ganglia block and less venous return from altered absent muscle tone and positive-pressure ventilation.

Reversal Agents

Sugammadex

Karen Serrano, MD

Sugammadex is a selective reversal agent for the nondepolarizing neuromuscular blockers rocuronium and vecuronium. Sugammadex acts rapidly, binding to the neuromuscular blocker with high affinity and trapping it in its hydrophobic core, resulting in full reversal of neuromuscular blockade in approximately 3 minutes for rocuronium, and slightly slower for vecuronium.[18,19] Sugammadex has been in use in Europe since 2005, and was approved for use in the United States in 2015, for reversal of neuromuscular blockade in patients undergoing surgery. It can be given when a surgical case ends earlier than anticipated, and also to restore spontaneous respiration in extubated patients with poor respiratory effort from prolonged neuromuscular blockade. Sugammadex is also approved for emergent reversal of rocuronium-induced neuromuscular blockade in a "can't intubate, can't ventilate scenario" in the operating room. This raises the question of whether sugammadex is appropriate for use in ED settings, since ED providers may also face a "can't intubate, can't ventilate" scenario. While having a reversal agent for a failed airway sounds promising for ED providers, expert consensus suggests that sugammadex should not be relied on as a panacea in the "can't intubate-can't ventilate scenario.[20–22] First of all, the 3 minutes required for reversal of neuromuscular blockade, plus the time trying to establish the failed airway, can result in prolonged hypoxia. Several published case reports of sugammadex in a failed airway scenario in the operating room describe patients who remained difficult to ventilate and ultimately required a surgical airway, even after complete reversal of neuromuscular blockade.[20,22] Experts agree that when facing a "can't intubate, can't ventilate" scenario, emergency providers should proceed with failed airway algorithms and use backup methods including video laryngoscopy, supraglottic airways, and ultimately, cricothyrotomy, rather than relying on sugammadex.[20–22] An area of promise for sugammadex in the ED, however, is for evaluation of the patient with neurologic injury. In a head injured or stroke patient intubated with rocuronium or vecuronium, sugammadex could rapidly reversal neuromuscular blockade, allowing a detailed neurologic exam immediately. The dose of sugammadex is 2 mg/kg or 4 mg/kg, depending on the depth of neuromuscular bloackade as measured by train of fours, or 16 mg/kg for emergent reversal in "can't intubate, can't ventilate" scenario.[26] Dosing is based on ideal body weight.

VIDEO LARYNGOSCOPY

Video laryngoscopes use an integrated monitor, antifogging mechanisms, and a high-resolution camera to indirectly visualize the glottis. ETT advancement and position are viewed through the video screen. All of the other elements of preparation, preoxygenation, and confirmation of intubation are unchanged.

Video laryngoscopy is either a rescue technique for failed direct intubation or the primary technique for routine and difficult airways. Video laryngoscopy improves glottic visualization and first-pass and overall intubation success rates compared to direct laryngoscopy in the emergency

setting.[4,27] It may require a longer first attempt to intubation interval. Success rates as a rescue device in patients who have failed direct laryngoscopy are reported as greater than 90%.[23] Video laryngoscopy is useful in those with potentially difficult airways, notably obese patients and those with limited neck mobility.[24] Avoid video approaches and use direct laryngoscopy if the camera could be obscured by blood or emesis.

Although the video laryngoscope handle has the familiarity of the traditional laryngoscope, the operator performs the intubation watching a video screen rather than looking into the oropharynx. The angle of the blade and transmission to the monitor creates a magnified view and provides views that cannot be obtained through direct laryngoscopy. The device can be used in patients with limited oral opening and with the neck in neutral position. These are advantages in patients with difficult airways or restricted cervical spine mobility. These devices also allow shared visualization and video recording useful for quality review, education, and training.

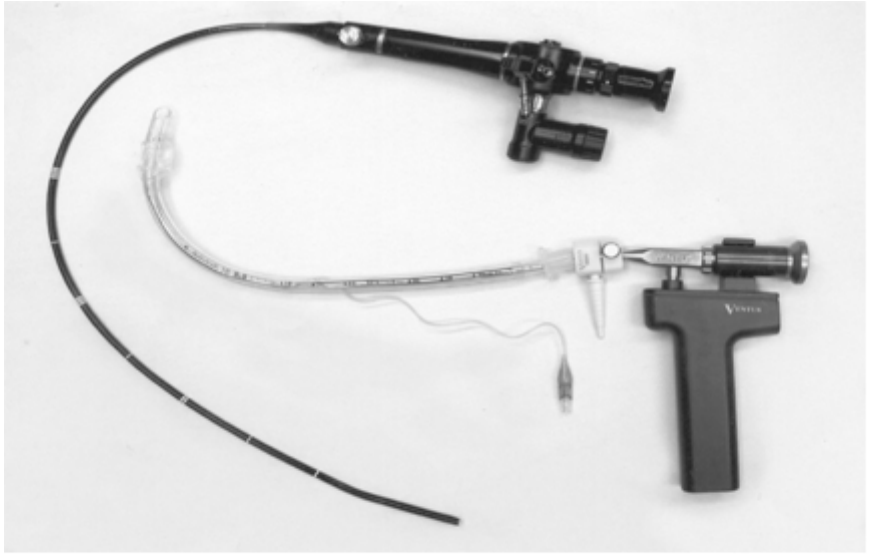
The two most studied video laryngoscopes are the **GlideScope Video Laryngoscope**® (Verathon, Bothell, WA) and the **C-MAC Video Laryngoscope**® (Karl Storz, Tuttlingen, Germany). Both devices offer a sharp-angled blade that is best used with malleable stylets or rigid stylets designed specifically for this purpose. Blades similar in shape to Macintosh and Miller blades, pediatric sizes, and disposable blades are available. Comparative studies between devices are limited, and no significant difference in success has been clearly demonstrated.

The technique for both blades differs from traditional laryngoscopy, in that a midline insertion is preferred and a tongue sweep is not needed. Once past the teeth, the operator identifies the midline by finding the uvula. The blade is then slowly advanced down the tongue until the epiglottis is seen. The ideal view is usually obtained by insertion into the vallecula, much like a Macintosh blade. The handle is then gently tilted forward until visualization of the glottis opening is obtained.

FIBEROPTIC LARYNGOSCOPY

The flexible fiberoptic laryngoscope is a valuable adjunct when anatomic limitations prevent visualization of the vocal cords.[24] Clinical examples include conditions that prevent opening or movement of the mandible, massive tongue swelling from angioedema, upper airway infections, congenital anatomic abnormalities, and cervical spine immobility. Flexible fiberoptic scopes allow visualization of the posterior pharynx, glottis, and laryngeal structures (Figure 29–3).

FIGURE 29–3.
A fiberoptic laryngoscope and a Shikani endoscope [Clarus Medical LLC, Minneapolis, MN].



Use of a fiberoptic scope requires instruction, facility, and practice, often initially in the simulation lab. Fiberoptic scopes allow airway assessment in select patients before attempting intubation. If equipment or expertise is not available in the ED, consult an expert with fiberoptic skills and tools.

Contraindications to fiberoptic intubation are relative. The procedure requires time to set up and usually a compliant, spontaneously breathing patient. Patients needing an immediate airway, with near-complete obstruction, with large bleeding or vomitus, and who cannot be ventilated to maintain saturation, are poor candidates.

Topical anesthesia is essential to fiberoptic intubation success. Use atomized or nebulized topical anesthetics, such as lidocaine or tetracaine. An antisialagogue, such as glycopyrrolate, 0.01 milligram/kg, reduces secretions and enhances topical anesthesia but should be given 20 minutes prior for best effect. Sedation is often required because most patients are spontaneously breathing and aware. If using the nasal route, instill a topical vasoconstrictor such as phenylephrine or oxymetazoline. Nasal viscous lidocaine followed by a nasal airway allows topical anesthesia and enhanced passage of the scope through the airway, although remember to remove the nasal tube prior to the passage of an ETT.

The nasal route allows easier midline airway positioning, and the optic tip enters the glottis at a less acute angle. Oral obstruction, such as tongue or posterior pharyngeal swelling, is a common indication for nasal fiberoptic intubation. If using the oral route, tongue extrusion and anterior

mandibular displacement help. Fiberoptic equipment is more frequently damaged transorally, so use a bite block. In the emergent setting, the nasal approach is preferred to the oral route in an upright, awake patient.

To begin the procedure, focus the eyepiece and lubricate the flexible shaft. Immerse the lens at the tip of the laryngoscope in warm water or apply antifogging solution. Newer flexible scopes use video technology, not fiberoptics, and interface directly with video laryngoscope monitors.

Continuously monitor pulse oximetry, and reduce the gag reflex with topical anesthetic. After attaching the oxygen tubing to the suction port, intermittent insufflation of oxygen at 10 to 15 L/min will keep the optic tip clear.

The adapter initially is removed from an ETT. If possible, use a tube that is at least 7.5 mm in inner diameter; slip the lubricated tube over the shaft up to the handle. The distal end of the fiberoptic laryngoscope must extend beyond the end of the ETT. Hold the laryngoscope in the left hand to control tip deflection while advancing it through the cords. The laryngoscope will function as a stylet for the tube. After the laryngoscope is in the trachea, the ETT is advanced, and the laryngoscope is removed.

Another option is to insert a warmed nasotracheal tube into the nasopharynx, stopping just proximal to the posterior pharynx. Dilating with lubricated nasopharyngeal airways before placement can be helpful. Then insert the scope through the ETT, and direct the fiberoptic tip into the glottis. This technique provides the assurance that the tube can be passed and allows the scope to bypass the secretion-laden anterior nares. Advancing the scope through the cords is the greatest technical challenge and requires good glottic anesthesia. Spraying 4% lidocaine through the working channel when the scope is over the glottic opening provides further suppression of the gag or cough reflex. Once the scope is through the cords, the tube is gently passed over the scope in a Seldinger technique. Resistance at the cords is best overcome with tube rotation rather than forceful insertion.

BLIND NASOTRACHEAL INTUBATION

Blind nasotracheal intubation is helpful in situations in which laryngoscopy may be difficult, RSI is contraindicated, and flexible fiberoptics are not available to facilitate nasal intubation. This technique is particularly useful in patients in whom oral intubation is impossible due to obstruction, such as severe angioedema, or with limited oral opening, such as fracture or recent surgery. Severely dyspneic patients with congestive heart failure, chronic obstructive pulmonary disease, or asthma who are awake often cannot remain supine but may tolerate nasotracheal intubation in the sitting position. This technique is now rarely used given the other options available; do not try this in an emergency without prior practice or unless a physician with prior experience is at hand to direct you in the procedure to avoid failure.

To minimize epistaxis, spray both nares with a topical vasoconstrictor anesthetic. Select a cuffed ETT 0.5 to 1.0 mm smaller than optimal for oral intubation. Verify the integrity of the cuff and the tube adapter to ensure a snug fit. Use universal precautions. Insert a nasal airway, first in one nare and then in the other, to determine which is more patent. Select the nare for intubation that is the largest and easiest to maneuver.

Have an assistant immobilize the patient's head and maintain it in a neutral or slightly extended position ("sniffing position"). The intubator stands at the side of the patient, with one hand on the tube and with the thumb and index finger of the other hand straddling the larynx. Advance the lubricated tube along the nasal floor on the more patent side. Facing the bevel against the septum helps minimize abrasions of the Kiesselbach plexus. Steady, gentle pressure or slow rotation of the tube usually bypasses small obstructions. Pass the tube *straight back toward the occiput* (not upward), and then advance it while rotating it medially 15 to 30 degrees until maximal airflow is heard through the tube. Then, gently, but swiftly, advance the tube at the *initiation (upswing) of inspiration*. Entrance into the larynx may initiate a cough, and most expired air should exit through the tube even though the cuff is uninflated. **If the patient can speak, the trachea was not intubated; remove the tube**.

You may palpate or externally see the tube enter the trachea toward the carina. The normal distance from the external nares to the carina is 32 cm in the adult male and 27 to 28 cm in the adult female. Therefore, **the optimal initial depth of tube placement for nasotracheal intubation in adults at the nares exit is 28 cm in men and 26 cm in women**. Confirm the tube placement as with oral intubation, and suction the tube before initiating positive-pressure ventilation.

If nasotracheal intubation is unsuccessful, carefully inspect the neck to identify tube malposition. Most commonly, the tube is in the pyriform fossa on the same side as the nostril used. A lateral neck bulge may be seen or palpated. Withdraw the tube into the retropharynx until breath sounds are heard. Then redirect the tube while manually displacing the larynx toward the side of the previous bulge. If there is no contraindication, flexing and rotating the neck to the ipsilateral side while the tube is rotated medially often is effective. If the tube hangs up on the vocal cords, shrill, turbulent air noises will be heard. The tube can be rotated slightly to realign the bevel with the cords.

The risk of inadvertent intracranial passage of a nasotracheal tube is extremely low. Severe traumatic nasal or pharyngeal hemorrhages are relative contraindications to nasotracheal intubation.

Serious complications of nasotracheal intubation are rare. The most common complication is epistaxis from inadequate topical vasoconstriction, excessive tube size, poor technique, or anatomic defects. Excessive force can damage the nasal septum or turbinates. Retropharyngeal lacerations, abscesses, and nasal necrosis are reported. Once the patient is stabilized, the nasotracheal tube can be electively replaced with an oral tube. If left in place for more than 48 hours, virtually all patients will have evidence of sinus blockage on imaging and many develop clinical infection.

DIFFICULT AIRWAY

The difficult airway is one in which mask ventilation or tracheal intubation fails or is likely to fail. Approximately 1% to 3% of attempts at tracheal intubation fail with standard techniques. *Difficult mask ventilation* is the inability to maintain oxygen saturation above 90% despite optimal positioning and airway adjuncts. *A failed airway* is defined as three unsuccessful attempts at intubation by an experienced operator or failure to maintain oxygenation.[25] The key to difficult airway management is expecting it to happen, preparing with a plan and expertise, and placing the appropriate airway equipment ready in one location at the bedside (**Table 29–10**).

Table 29–10

Suggested Difficult-Airway Cart Equipment

- Endotracheal tubes: assorted sizes, designs, tip control, fiberoptic
- Laryngoscope blades: alternate sizes and designs, fiberoptic (extra bulbs)
- Laryngoscope handles: extra batteries
- Stylets: Eschmann bougie, semi-rigid, hollow, light wand
- Syringes, fixators, and Magill forceps
- 4% lidocaine, viscous lidocaine
- 1% phenylephrine (Neo-Synephrine), oxymetazoline
- Suction catheters
- Rescue devices:
  - Laryngeal mask airways
  - Combitube® (Sheridan Catheter Corp., Argyle, NY)
  - King LT® (King Systems, Noblesville, IN)
- A surgical airway option:
  - Transtracheal jet ventilation equipment
  - Cricothyrotomy equipment
- Tracheostomy tubes
- Video laryngoscopy
- Diagnostic flexible nasopharyngoscope
- Intubating flexible scope

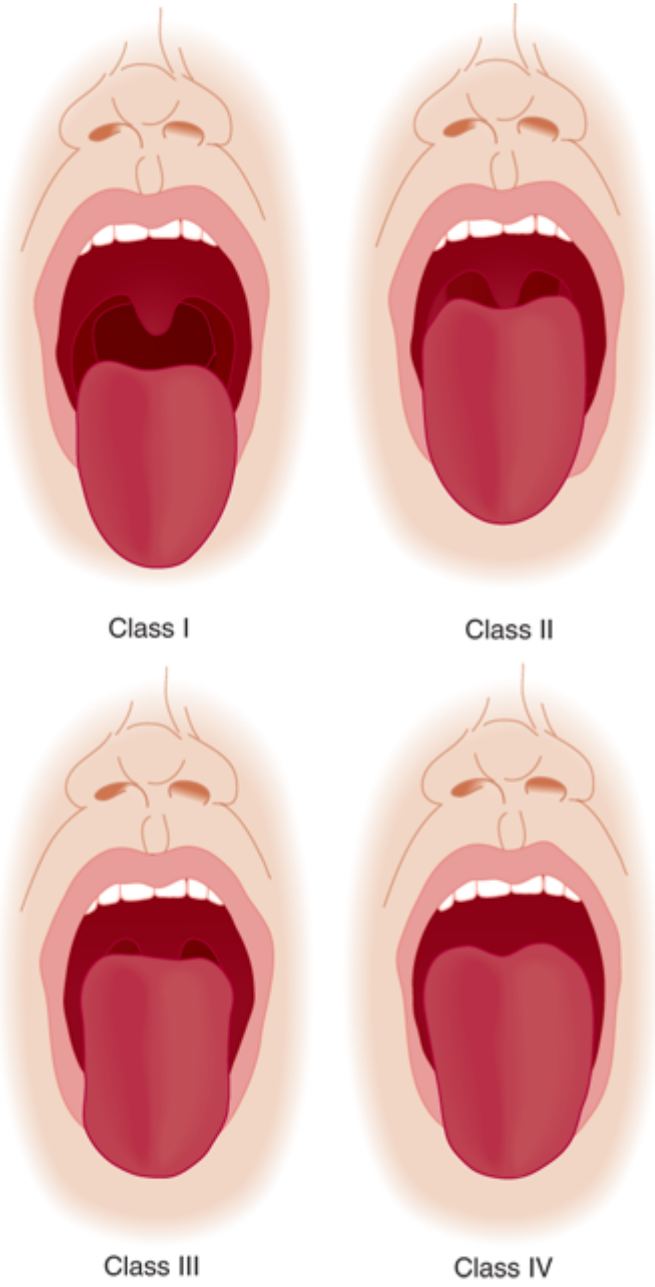
Before any attempt at intubation, assess potential difficulties for bag-valve mask ventilation and laryngoscopy. The presence of two of the following factors increases the likelihood of difficult bag-valve mask ventilation: facial hair, obesity, edentulous patient, advanced age, and snoring. An inability to adequately ventilate with a bag-valve mask is usually solved by better positioning, jaw thrust, a tighter seal with two-person bagging, and the use of oral and nasal airways.[29] A lubricant may improve the seal in a bearded patient; dentures left in place facilitate

bag-valve mask ventilation, but remove dentures before any intubation attempt. External features associated with difficult intubation include obesity, a short neck, small or large chin, buckteeth, high arched palate, and any airway deformity due to trauma, tumor, or inflammation.

Most studies of airway difficulty use a grading system identified through laryngoscopic view. Such methods are not practical in the ED. A simple, systematic, and rapid evaluation of the airway is used to predict a potentially poor laryngoscopic view before RSI and neuromuscular blockade.[25,28] The mandibular opening in an adult should be at least 4 cm, or **two to three fingerbreadths**. The ability of the mandible to accommodate the tongue can be estimated by the distance between the mentum and the hyoid bone, which should be **three to four fingerbreadths**. A small mandible is more likely to have a tongue obstruction impairing visualization during laryngoscopy. An unusually large mandible also may impair visualization by elongating the oral axis. A high, anterior larynx is possible if the space between the mandible and top of the thyroid cartilage is narrower than two fingerbreadths. The degree to which the tongue obstructs the visualization of the posterior pharynx on mouth opening has some correlation with the visualization of the glottis. Assess this with the **Mallampati criteria**, with classes III and IV being associated with poor visualization and higher failure rates (up to 5% and 20%, respectively; **Figure 29–4**). The *Mallampati approach is limited in that it requires an upright patient who can open his/her mouth spontaneously*; attempting this in a supine patient or with a tongue depressor will not accurately predict laryngoscopic views.

FIGURE 29–4.

Classification of tongue size relative to the size of the oral cavity as described by Mallampati and colleagues. Class I: Faucial pillars, soft palate, and uvula can be visualized. Class II: Faucial pillars and soft palate can be visualized, but the uvula is masked by the base of the tongue. Class III: Only the base of the uvula can be visualized. Class IV: None of the three structures can be visualized.



Source: J.E. Tintinalli, J.S. Stapczynski, O.J. Ma, D.M. Yealy, G.D. Meckler, D.M. Cline: Tintinalli's Emergency Medicine: A Comprehensive Study Guide, 8th Edition
www.accessmedicine.com

Neck immobility interferes with the ability to align the visual axes by preventing the desired "sniffing position." Neck immobility can occur from a cervical collar or structural changes that include fracture, dislocation, or arthritis. If there is no suspicion of cervical injury, assess atlanto-occipital extension; if unimpeded, laryngoscopy will likely be easier.

Airway obstruction presents another challenge to airway management. If evidence of obstruction is present, consider the location of the obstruction, whether it is fixed (e.g., tumor) or mobile (e.g., epiglottis), and how rapidly it is progressing. The location may determine which approach or rescue device can be used. Oral airway obstruction from angioedema of the tongue may limit the physician to nasal techniques or a surgical airway (see chapter 30, "Surgical Airways"). Bag-valve mask ventilation is more likely to be successful in mobile as opposed to fixed obstruction. The speed of progression determines whether the patient can await alternative management elsewhere.

MECHANICAL VENTILATORY SUPPORT

Ventilators are pressure or volume cycled. Volume-cycled ventilators are used routinely in EDs. Decisions with regard to mechanical ventilatory support in the ED include the rate, mode, fraction of inspired oxygen, minute ventilation, and use of positive end-expiratory pressure.

There are three common ventilator methods for providing the tidal volume: continuous mechanical ventilation, assist-control, and synchronized intermittent mandatory ventilation. Continuous mechanical ventilation is most commonly used in the operating room for heavily sedated or paralyzed apneic patients. The **assist-control mode** is preferred initially for patients in respiratory distress, allowing inspiration triggered by either the intrinsic effort or an elapsed time interval. The ventilator provides a "controlled" breath at a predetermined tidal volume during the selected time cycle or sooner if triggered by the patient's effort. In the **synchronized intermittent mode**, a predetermined number of ventilator-generated tidal volumes exists, and ventilation is synchronized to patient effort. If the intrinsic respiratory rate is below the set rate, synchronized intermittent mode acts like the assist-control mode. However, if the patient is breathing above the set respiratory rate, the efforts are not assisted; this increases the work of breathing, making synchronized intermittent mode undesirable in the ED. Initial ventilator settings and goals can be found in Table 29–11. Obtain an arterial blood gas after initiation of mechanical ventilation to ensure proper ventilation.

Table 29–11

Initial Ventilator Settings and Goals

Ventilator Parameters	Ventilator Settings
Mode	Assist-control
FIO_2	Begin with 100% oxygen
Tidal volume	6 mL/kg (ideal body weight) to start
Respiratory rate	12 breaths/min
Inspiratory flow rate	60 L/min
Inspiratory:expiratory ratio	1:2 or 1:3 ratio
Positive end-expiratory pressure	Begin with 5 cm H_2O, titrate to 10 cm H_2O
Ventilation goals	PaO_2: 60–90 mm Hg $PaCO_2$: 40 mm Hg pH: 7.35–7.45 FIO_2 of 40%–60% Inspiratory peak pressure <35 cm H_2O

Abbreviations: FIO_2 = fraction of inspired oxygen; $PaCO_2$ = partial pressure of arterial carbon dioxide; PaO_2 = partial pressure of arterial oxygen.

Adjust initial mechanical ventilation based on responses to oximetry, capnography, and plateau pressures.[30] Minimize plateau pressures and tidal volumes to reduce the risk of lung injury. Tidal volumes of 6 cc/kg are best for lung protection. In some cases, such as obstructive airway disease,

hypercapnia is tolerated to achieve lower plateau pressures. Positive end-expiratory pressure, starting at 5 cm H_2O and titrating to 10 cm H_2O if tolerated, can prevent alveolar collapse and improve oxygenation. Unless a contraindication exists, elevate the head of the bed 30 degrees to prevent aspiration and ventilator-associated pneumonia and improve lung recruitment. A prone position aids to improve lung segment recruitment, although this is not often started in the ED and is usually deployed after paralysis and the other measures fail. When possible, titrate oxygen to less than 60% to prevent oxygen toxicity.

Maintain patient sedation and analgesia initially during mechanical ventilation, particularly if the patient is paralyzed.[31] This is usually best achieved with an initial bolus followed by an IV infusion titrated to need. Intermittent boluses are reserved for anticipated short-term mechanical ventilation (**Table 29–12**). The goal is the optimal sedation (not deeper or longer than needed) for comfort and to allow recovery; targeting clinical assessments of sedation, blood pressure, and heart rate are common. The goals include amnesia, pain control, and the ability to ventilate without neuromuscular blockade if possible. Later, sedation withdrawal is an option based on response and can limit postextubation cognitive changes.

Table 29–12

Sedation During Mechanical Ventilation

Drug	Initial Bolus	Starting Infusion	Comments
Fentanyl	1-2 micrograms/kg IV	0.5–1 microgram/kg/h	Often combined with midazolam
Remifentanil	1.5 micrograms/kg IV	0.5–1 microgram/kg/h	Ultra-short-acting
Midazolam	0.05 milligram/kg IV	0.025 milligram/kg/h	Often combined with fentanyl
Propofol	0.5 milligram/kg IV	20-50 micrograms/kg/min	Can cause hypotension
Ketamine	0.5–1 milligram/kg IV	0.5 milligram/kg/h	May provide bronchodilation; sympathetic stimulation

EXTUBATION

This maneuver is not common in the ED but may be required in settings of rapid recovery or after prolonged ED care. Before extubation, assess respiratory sufficiency by determining inspiratory capacity—it should be at least 15 mL/kg. Ideally, there should be no intercostal or suprasternal reactions, and the patient hand grip should be firm.

After suctioning secretions and ensuring ongoing adequate oxygenation, explain the procedure to the patient. Positive-pressure ventilation with a mask will help while the cuff is deflated. *Remove the tube at the end of a deep inspiration.* Continue giving oxygen by mask to prevent secretory reaccumulation.

Observe closely for stridor after extubation. Postextubation laryngospasm is treated initially with positive-pressure oxygen or using a high-flow oxygen (including an Optiflow^{TM}) delivery system. If necessary, nebulized racemic epinephrine (0.5 mL of 2.25% epinephrine in 4 mL of saline) helps when stridor suggests laryngospasm or upper airway edema secondary to tube placement and removal.

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