

Airway Management

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OVERALL BOTTOM LINE

- Airway management is a vital life-saving skill for the ICU provider.
- The provider should be capable of using a broad range of devices including endotracheal tubes, supraglottic devices, and direct and video laryngoscopes.
- Understanding airway anatomy, performing a thorough airway examination, and recognizing potential challenges of both bag-mask ventilation as well as endotracheal intubation are essential.
- Formulating a plan (often with a backup in mind), proper monitoring, meticulous attention to patient positioning, and immediate availability of equipment and medications are necessary to provide safe and effective care.
- It is crucial to know when to call for assistance, when to attempt a 'rescue technique,' and when escalation to invasive airway management (i.e. cricothyrotomy or tracheostomy) is necessary.

Functional anatomy of the upper airway

- The human airway consists of two openings: the nose, which leads to the nasopharynx, and the mouth, which leads to the oropharynx. These passages are separated anteriorly by the palate and they join posteriorly, although still separated via an imaginary horizontal line extending posteriorly from the palate. Inferiorly past the base of the tongue, the epiglottis separates the oropharynx from the laryngopharynx, or hypopharynx. The epiglottis serves to protect against aspiration by covering the opening of the larynx (the glottis) during swallowing. The larynx is a cartilaginous skeleton comprised of nine cartilages as well as ligaments and muscles. The thyroid cartilage functions partly to shield the vocal cords. Inferior to the cricoid cartilage lies the trachea, which extends to the carina at approximately T5 where it branches into the right and left mainstem bronchi. The right mainstem bronchus takeoff is more straight and vertical, making it the most likely path taken by a deep endotracheal tube placement.
- Innervation of the upper airway is from the cranial nerves. Sensation to mucous membranes of the nose is supplied by the ophthalmic division (V1) of the trigeminal nerve anteriorly and the maxillary division of the same nerve posteriorly. The glossopharyngeal nerve provides sensation to the posterior third of the tongue as well as the tonsils and undersurface of the soft palate.
- Below the epiglottis, sensation is supplied by branches of the vagus nerve. The superior laryngeal branch divides into external and internal segments. The internal branch provides sensation to the larynx between

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the epiglottis and the vocal cords. Another branch of the vagus nerve, the recurrent laryngeal nerve, provides laryngeal sensation below the vocal cords as well as the trachea.

- Motor supply to the muscles of the larynx is from the recurrent laryngeal nerve, with the exception of the cricothyroid muscle (vocal cord tensor), which is innervated by the external branch of the superior laryngeal nerve. All vocal cord abductors are controlled by the recurrent laryngeal nerve.

Airway assessment

- Complete airway assessment includes taking a history and a physical examination, noting any findings indicative of possible difficulty with mask ventilation, endotracheal intubation, or both.
- While airway management in the ICU can often be urgent or even emergent, failure to recognize predictors of a difficult airway can have potentially dire consequences.
- The most likely *predictor of airway difficulty* is a history of previous difficulty. Other ‘red flags’ include a history of head and/or neck radiation, airway or cervical spine surgeries, obstructive sleep apnea, presence of a mediastinal mass, or certain chromosomal abnormalities or inherited metabolic disorders.
- Time of last oral intake should be determined, if at all possible, as clear liquids within 2 hours or solid meals within 8 hours put the patient at higher risk for aspiration. Other risk factors for aspiration include gastroesophageal reflux disease (GERD), hiatal hernia, pregnancy, diabetes (gastroparesis), and morbid obesity.
- Physical examination should include assessment of the oral cavity as well as external characteristics of the head and neck, again noting potential difficulties with mask ventilation and/or intubation (Table 1.1).
- Mouth opening, presence of facial hair, and presence or absence of teeth/dentures should be assessed. Any loose teeth should be noted and dentures should be removed to avoid dislodgment and potential aspiration.
- The *Mallampati classification* describes the size of the tongue in relation to the oral cavity, which is a clinical sign developed to aid in the prediction of endotracheal intubation difficulty. The test is traditionally performed on a seated patient with the head in a neutral position, mouth opened, with the tongue protruding with no phonation. Scores are assigned based on the visibility of the oropharyngeal structures. A Mallampati class I score is indicative of relatively easy endotracheal intubation while a score of IV suggests the possibility of difficult intubation when taking other clinical signs into account (Figure 1.1).
- Examination of the neck should note any masses or goiters as well as tracheal deviation from the midline. One should note neck circumference, the ability to flex and extend the neck, as well as thyromental distance.

Table 1.1 Predictors of difficulties with mask ventilation and/or intubation.

Predictors of difficult mask ventilation	Predictors of difficult laryngoscopy
Edentulous	Overbite
Age 55 years or older	Small mouth opening <3 cm
Male patient	Mallampati class III or IV
Presence of facial hair	Thyromental distance <3 fingerbreadths
Obesity	Neck circumference >43 cm (17 inches)
Obstructive sleep apnea	Limited cervical mobility

Equipment

- Proper preparation is essential for all airway management situations.
- Essential equipment includes oxygen source (wall or tank), suction, bag-mask ventilation circuit, direct and/or video laryngoscopes, endotracheal tubes of several sizes, supraglottic airway device, blood pressure/ECG/pulse oximetry, and CO₂ detection device.
- Supraglottic airway devices include the laryngeal mask airway (LMA) which is inserted into the patient's mouth and sits above the glottis. As these devices do not protect against aspiration of gastric contents, in the ICU they are generally limited to rescue devices in situations where mask ventilation and endotracheal intubation are difficult.
- While numerous types of direct laryngoscopes are available, the two most common are the Macintosh blade (MAC) and the Miller blade. Both come in multiple sizes, but typically a MAC 3 or Miller 2 are suitable for a standard-sized adult.
- In recent years, *video laryngoscopes*, a form of indirect laryngoscopy, have become readily available in most institutions. Video laryngoscopes differ from one another in the shape of the blade, proper position when inserted into the mouth, location of the video source, and reusable/disposable parts. Glidescope® has its own (non-disposable) stylet which accompanies the unique shape of its blade. One potential problem with video laryngoscopy is that, while it may provide a clear view of the glottic opening, one still may have difficulty maneuvering an endotracheal tube into proper position.
- Endotracheal tubes (ETTs) are also available in various materials and sizes. Most commonly used in the ICU are ETTs made from polyvinyl chloride with a beveled tip to allow better visualization of insertion, a side hole (Murphy's eye) to prevent total occlusion in the event of a mucous plug, and an inflatable cuff. ETTs are sized according to internal diameter in millimeters and the appropriate size for adults is typically 7.0–8.0 mm. Bear in mind that if bronchoscopy is needed, ETTs smaller than 7.5 mm may be too narrow to accommodate an adult bronchoscope.

Positioning

- Proper patient positioning is of utmost importance and should be achieved prior to any airway intervention, particularly if direct laryngoscopy is to be attempted. Proper positioning can be the difference between a successful and unsuccessful laryngoscopy attempt.
- With the provider standing at the head of the bed, the patient's head should be as far towards the head of the bed as possible. The height of the bed should be to the provider's preference.
- Proper positioning creates a direct line of sight from the patient's mouth to the larynx. This is accomplished using approximately 30° of cervical flexion using pillows/blankets along with extension of the atlanto-occipital joint, the classic 'sniffing position.'
- Positioning obese patients may be particularly challenging. This can be accomplished by forming a ramp, elevating the upper back and shoulders in order to accommodate adequate cervical flexion. Confirming horizontal alignment of the external auditory meatus with the sternal notch can be a useful guide.

Preoxygenation

- Adequate preoxygenation should be provided in all but the most emergent situations.
- The aim is to replace nitrogen in the lungs with oxygen. This increases the length of time before desaturation when the patient is apneic ('apnea time'), providing a margin of safety in case ventilation and intubation become difficult.
- Preoxygenation can be performed using a facemask, continuous or bilevel positive airway pressure, or a high flow nasal cannula (HFNC) providing 100% oxygen at flows of at least 10 L/min. It typically requires approximately 3 minutes of normal tidal volume breathing to achieve an end-tidal oxygen concentration of approximately 90%.

- Given normal functional residual capacity (FRC) of about 2 L, and an oxygen consumption rate of about 200–250 mL/min, a properly preoxygenated adult should have an apnea time of about 5–8 minutes before significant desaturation. Reductions in apnea time should be expected in conditions in which FRC is decreased (i.e. obesity, pregnancy, tense ascites) or conditions of increased oxygen consumption (i.e. sepsis, pregnancy, hyperthyroidism).

Bag and mask ventilation

- *The ability to ventilate a patient using a bag and mask is by far the most important skill for any airway provider to master.* The inability to intubate the trachea is not fatal if mask ventilation is possible, making it a vital component of the ASA difficult airway algorithm.
- Relative contraindications to mask ventilation are full stomach/regurgitation risk, severe facial trauma, and unstable cervical spine fractures.
- Mask ventilation is performed with the provider holding the mask in his or her left hand with the mask over the patient's nose and mouth with the third, fourth, and fifth digits holding the mandible and lifting the face into the mask while the thumb and index finger form a 'C' shape around the collar aspect of the mask near the connection to the circuit. As the bag is squeezed one should note chest rise and condensation in the mask, and should hear no air escape which would indicate a leak due to an inadequate seal. Care should be used not to compress the submandibular tissue as this can collapse the airway and make ventilation more difficult.
- If mask ventilation proves difficult, one can employ a two-handed technique in which one provider holds the mask in both hands with their thumbs on top of the mask and remaining digits on the mandible lifting the face into the mask while an assistant squeezes the bag. Oral and nasal airways can also be useful as they pull the tongue and epiglottis away from the posterior wall of the pharynx, allowing more airflow.

Laryngoscopy and confirmation of placement

- After ensuring proper preparation, equipment set-up, functioning monitors, positioning and preoxygenation, the patient is typically administered an apnea-inducing medication as well as a paralytic agent, both of which are chosen based on patient conditions as well as the clinical situation. It should also be noted that in certain conditions such as cardiac arrest, induction agents may not be necessary.
- When the patient is deemed appropriately anesthetized, the laryngoscope is held in the provider's left hand while the right hand opens the patient's mouth using his or her thumb and index finger in a scissoring motion. The laryngoscope is then inserted into the mouth using care not to damage the patient's lips or teeth. In the case of the curved MAC blade, the tongue is swept to the left and the tip of the blade placed in the vallecula just anterior to the epiglottis, while the straight Miller blade is inserted in midline position beneath the epiglottis. The handle of the laryngoscope is lifted upwards and anteriorly, exposing the vocal cords. The handle should never be tilted backwards as this can result in dental damage. The ETT is then inserted through the vocal cords under direct visualization. After ETT insertion, the stylet (if used) is removed as is the laryngoscope. The pilot balloon is then inflated with air using a 10 mL syringe to no more than 30 mmHg of pressure.
- To confirm tracheal placement, the ETT is connected to a bag ventilation circuit and ventilated, observing bilateral chest rise, condensation in the ETT, and, most importantly, continuous end-tidal CO₂ via capnography – considered the gold standard. If continuous end-tidal CO₂ is not detected, esophageal intubation should be suspected and laryngoscopy should be reattempted.
- The distal tip of the ETT should lie beyond the vocal cords but above the carina, avoiding mainstem intubation. In adults this typically correlates to 21–23 cm at the patient's lip. A CXR should be ordered immediately after placement to confirm proper position.

- Video 1.1 demonstrates a successful endotracheal intubation of a morbidly obese patient. Note the ready availability of all necessary equipment including suction, laryngoscope, ETT, and oral airway. Also, note the proper patient positioning, including approximately 35° cervical flexion aided by the use of multiple blankets to ramp the shoulders as well as slight head extension. This combination allows for a nearly straight line of sight from the open mouth to the trachea. A MAC blade is used in the left hand and it sweeps the tongue to the side after the right hand scissors the mouth open. The blade is placed in the vallecula. Force is applied in a 45° direction to visualize the glottis opening, not rocked back against the upper incisors. The ETT is directly visualized as it passes between the vocal cords. The laryngoscope is then removed, and the ETT cuff is inflated with no more than 10 mL of air. While bilateral breath sounds and presence of fog in the ETT should indicate proper placement, the gold standard for proper placement is continuous end-tidal CO₂ waveform capnography.

Rapid sequence induction

- This is a specialized method of induction used when the risk of pulmonary aspiration is particularly high.
- The goal is to achieve optimal intubating conditions in the fastest time possible.
- After preoxygenation, cricoid pressure is held by an assistant while induction agents (see Chapter 2 for agents and dosages) are given followed by 1.5 mg/kg of succinylcholine or 1 mg/kg of rocuronium, and laryngoscopy is attempted without mask ventilation. Cricoid pressure is maintained until confirmation of tracheal intubation is observed.

Difficult airway

- Most difficult airways can be anticipated, and care should always be taken to recognize them with proper assessment, as unanticipated airway difficulties subject the patient to potential hypoxia, cardiovascular collapse, and neurologic damage.
- A distinction should be made as to whether the potential difficulty lies in the ability to mask ventilate, to intubate, or both.
- A good rule of thumb is to never intentionally make a patient apneic unless one is certain that ventilation will be possible.
- Proper planning and set-up, availability of equipment, positioning, and adequate preoxygenation become even more important when airway difficulty is suspected.
- In the setting of an anticipated difficult airway, additional tools such as video laryngoscopes, fiberoptic bronchoscopes as well as additional providers with the ability to provide surgical airway access should be immediately available prior to induction.
- If intubation and mask ventilation are predicted to be difficult, airway topicalization with local anesthetic and fiberoptic intubation while awake with minimal sedation is the gold standard. This should be performed with an open emergency tracheostomy set nearby as well as a provider capable of performing a surgical airway procedure. One may also attempt an 'awake look' by titrating small doses of a non-apnea-inducing hypnotic-like ketamine until a brief exam under video or direct laryngoscopy is tolerated. If this view is acceptable, one can then induce as usual and intubate the patient with the particular device.
- In the undesirable scenario where intubation is found to be difficult after induction (unanticipated difficult intubation), an attempt should be made to mask ventilate the patient and assistance should be called. If mask ventilation is easy, one can then attempt another method of intubation while confirming proper positioning and bed height. If mask ventilation is difficult, one should attempt the two-handed mask ventilation technique or placement of an oral airway. If still difficult, supraglottic airway placement such as an LMA should be considered. If ventilation remains poor, emergency invasive airway placement is likely required.

Cervical spine disease

- Cervical spine injury, whether due to trauma, previous cervical fusion resulting in limited mobility, or inflammation from rheumatoid arthritis can present challenges for airway management. The presence of a cervical collar can also make airway management difficult. Evaluation of cervical flexion and extension is prudent, and, in the case of trauma, discussions with spine surgeons regarding cervical spine stability should take place.
- In the setting of an unstable cervical spine injury, intubation with a fiberoptic bronchoscope should take place. Alternatively, direct laryngoscopy while an assistant performs inline stabilization (holding the head firmly with both hands so as to not allow unintentional cervical flexion or extension by the laryngoscopist) may be attempted.

Extubation

- While the decision to extubate is partly driven by objective data, it also relies upon clinical judgment.
- Patients should have stable vital signs, an SpO_2 of at least 90% or an FiO_2 of 40% or less, $\text{PaCO}_2 < 50$ mmHg unless there is known chronic CO_2 retention, adequate tidal volumes on minimal pressure support, intact airway reflexes, and baseline mental status.
- One should also consider the specific situation such as difficulty of intubation, barriers to reintubation (e.g. jaw wired shut after maxillofacial surgery, significant airway edema), fluid balance, and acid–base balance.
- If there is any question of airway patency, one may consider performing a leak test (deflating the ETT cuff and listening for air movement around the ETT and observing a decrease in tidal volume) or extubating over an ETT exchanger with a backup ETT available in case reintubation becomes necessary.
- Patients with baseline pulmonary dysfunction may benefit from being extubated to BIPAP or HFNC.

Complications of intubation

Airway trauma

- Instrumentation of the airway can cause trauma to soft tissues as well as to teeth and lips.
- Although less common with modern ETTs, overinflation of cuffs (typically greater than 30 mmHg) can cause tissue ischemia, leading to inflammation and possibly tracheal stenosis as well as vocal cord paralysis from compression of the recurrent laryngeal nerve. Vocal cord paralysis can produce hoarseness and susceptibility to aspiration.

Physiologic effects of airway instrumentation

- Hypotension is a common response to induction and should be anticipated, especially in critically ill patients.
- Hypertension and tachycardia can be seen if inadequate anesthetic is provided.
- Laryngospasm, an involuntary closure of the laryngeal muscles, is a response to airway stimulation in the setting of light anesthesia. Severe hypoxia, from the inability to mask ventilate through the closed larynx, can result. Treatment includes gentle positive pressure with a mask. If this fails, deepening the plain of anesthesia as well as giving succinylcholine will typically relax the musculature.

Aspiration

- Critically ill patients often require airway management in the undesirable setting of a full stomach, or mechanical or physiologic motility disorders, making aspiration of gastric contents a feared complication.
- If suspected, the patient should be placed in the Trendelenburg position, the pharynx and trachea (if possible) suctioned, and the airway secured with an ETT as soon as possible.

- Therapy is typically supportive and antibiotics and bronchoscopic lavage are usually not necessary unless particulate aspiration is suspected or if signs of infection occur.

Reading list

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Images

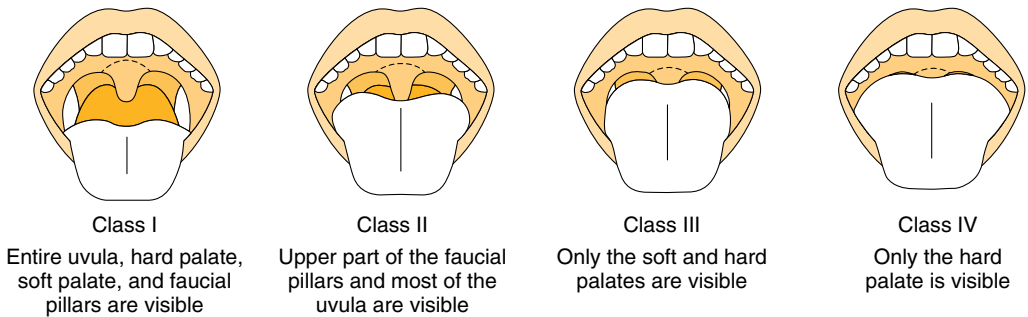


Figure 1.1 Mallampati classification.

Additional material for this chapter can be found online at:
www.wiley.com/go/mayer/mountsinai/criticalcare

This includes multiple choice questions and Video 1.1.

