Airway Evaluation and Management

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Introduction

The link between the practice of anesthesia and airway management is not entirely intuitive. How could anesthetizing a patient for a lower extremity procedure possibly impact that patient's airway or respiratory status? The answer lies largely in the profound respiratory side effects of most anesthetic medications. Despite the site of surgery or the anesthetic technique chosen, every patient receiving anesthetic care is exposed to a varying degree of risk of airway compromise. That is, all levels of sedation, general anesthesia, and regional anesthesia carry with them at least a small risk of airway obstruction and apnea. Therefore, every anesthesia provider must examine each patient in anticipation of a need to intubate and mechanically ventilate, regardless of whether or not such interventions were part of the primary anesthetic plan. A thorough airway examination and history, combined with expert airway management, guard against the life-threatening risks of airway obstruction and apnea.

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It is during the provision of general anesthesia that airway management is most commonly employed. General anesthesia renders patients insensate to noxious stimuli throughout their bodies and is therefore employed during a wide variety of surgical procedures from craniotomy and tonsillectomy to liver resection and prostatectomy. The intravenous induction of general anesthesia and apnea are most often synonymous. Expert airway management is the cornerstone of safety for any general anesthetic.

Airway management is not routinely employed during regional anesthesia. However, airway management could become necessary should the patient suffer an intravascular injection of local anesthetic that precipitates seizure or cardiovascular collapse. The same risks of apnea during sedation also apply, should the patient receive sedation either for the regional anesthetic itself, or during the ensuing surgical procedure.

Airway Anatomy

The human airway is a dynamic structure that extends from the nares and/or mouth to the alveoli. Obstruction can occur at any point because of anatomic collapse or a foreign body which includes liquids such as mucous, blood, and gastric contents.

Airway Evaluation

In addition to the inherent risks of apnea with all anesthetic techniques, management of the difficult airway continues to be a clinically important source of liability. The goal of airway evaluation is to risk stratify and predict which patients will be difficult to ventilate and/or intubate and form contingent strategies. Difficult mask ventilation occurs when there is an inadequate seal between the patient's face and the mask, there is a leak of oxygen from the facemask, or there is excessive resistance to the inflow or outflow of oxygen. Difficult laryngoscopy occurs when no portion of the glottis is visualized after multiple laryngoscopic attempts. A patient is defined as having a difficult airway if a conventionally trained anesthesiologist experiences difficulty with facemask ventilation of the upper airway, difficulty with tracheal intubation, or both (Fig. 9.1).

In order to predict difficult mask ventilation or difficult endotracheal intubation, each patient receiving anesthetic care should have a comprehensive airway history and physical examination performed (also see Chap. 8). Patients should be queried about airway complications that occurred during past anesthetics. A history of trauma during previous airway management to the patient's lips, teeth, gums, or mouth may indicate the presence of a difficult airway. Similarly, if the patient reports that many attempts were made to "insert the breathing tube" or that he or she was "awake" during previous intubations, a difficult airway should be considered. Medical conditions that classically may portend a difficult airway include a recent or remote history of facial trauma or surgery, obstructive sleep apnea, rheumatoid arthritis, pregnancy, epiglottitis, previous cervical fusion, neck masses, Down's syndrome, and other genetic syndromes such as Treacher-Collins and Pierre-Robin that have associated facial abnormalities. With a positive history, documentation regarding previous airway management should be reviewed.

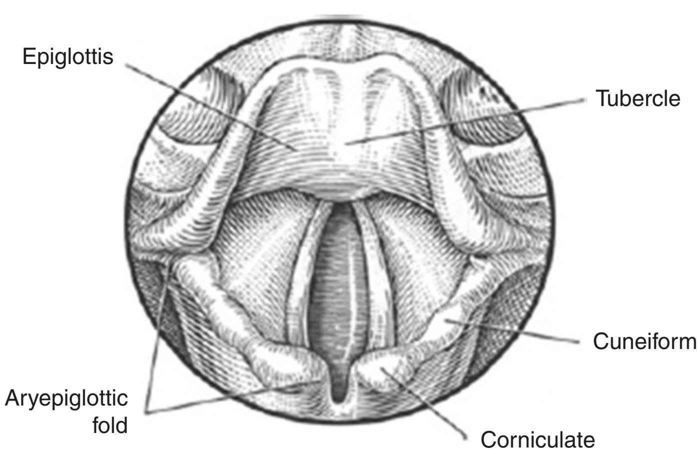

Fig. 9.1 The glottis and epiglottis. (Reproduced with permission from Finucane and Santora [3])

Multiple physical examination features have been correlated with a difficult airway (Table 9.1).

Every patient receiving anesthetic care should be thoroughly examined for the presence of these features. An adequate exam is difficult to accomplish without active participation and cooperation of the patient. That is, examinations performed solely by inspection may not only be incomplete, but may also be inaccurate. The most common examination performed to evaluate patients for the presence of a difficult airway is determination of what is known as the Mallampati Class. This classification system, first developed in 1985, seeks to predict difficult intubation by functionally assessing the ratio of the size of one's tongue to the size of one's oral cavity (Fig. 9.2).

Increasing difficulty with direct laryngoscopy has been correlated with Mallampati Class III and IV examinations. While no

Table 9.1 Components of the preoperative airway physical examination

Component	Nonreassuring finding
Length of upper incisors	Relatively long
Relation of maxillary and mandibular incisors during normal jaw closure	Prominent "overbite" (maxillary incisors anterior to mandibular incisors)
Relation of maxillary and mandibular incisors during voluntary protrusion of the jaw	Patient's mandibular incisors anterior to (in front of) maxillary incisors
Inter-incisor distance (mouth opening)	<3 cm
Visibility of uvula	Not visible when tongue is protruded with patient in sitting position (e.g., Mallampati class >II)
Shape of palate	Highly arched or narrow
Compliance of submandibular space	Stiff, indurated, occupied by mass, or non-resilient
Thyromental distance	<3 finger breadths or 6–7 cm
Length of neck	Short
Thickness of neck	Thick (neck size > 17 in.)
Range of motion of head and neck	Patient cannot touch tip of chin to chest or cannot extend neck

Reproduced with permission from Caplan et al. [2]

Fig. 9.2 Modified Mallampati classification system (Samsoon and Young)

single physical examination feature in isolation can accurately predict a difficult airway, most anesthesia providers incorporate the presence of multiple features to predict a difficult airway.

Mask Ventilation

Face mask ventilation is the most basic airway management intervention and is the first skill any student of anesthesia should seek to develop. Three goals need to be achieved for optimal facemask ventilation:

1. An optimal seal must be made between the mask and the patient's face
2. The patient's oropharynx must be opened by anterior displacement of the mandible into the facemask and extension of the head as seen in Fig. 9.3. Placement of an oral or nasal airway during facemask ventilation may assist in opening the oropharynx by creating an artificial passage for gases between the tongue and the posterior pharyngeal wall as seen in Fig. 9.4.
3. Sufficient positive pressure must be generated to overcome the resistance of the patient's upper airway, chest wall, and diaphragm to effect efficient gas exchange at the alveoli.

Fig. 9.3 Optimal facemask ventilation

Mask ventilation can be employed to augment patient's spontaneous tidal volumes as a temporizing measure before definitive airway management occurs via endotracheal intubation – as in the case of an intensive care unit patient slowly succumbing to respiratory failure from pneumonia. In the operating room, mask ventilation is most commonly employed to oxygenate and ventilate patients who are apneic from general anesthetic induction agents. Common errors in mask ventilation include pressing down too forcefully on the mask, causing posterior movement of the mandible and collapsing the oropharyngeal space; focus should be placed on anterior displacement of the mandible and "lifting" the mandible up to the mask. Another common source of improper technique is to have the fingertips of the hand holding the mask pressing into the submental tissue, collapsing the oral passageway; proper technique involves keeping the fingertips on the mandibular bone.

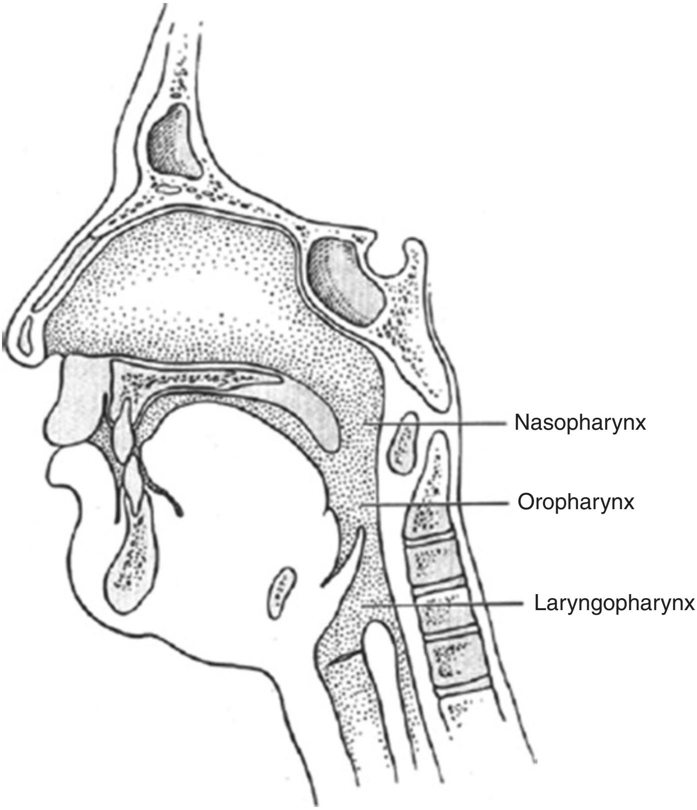

Fig. 9.4 Upper airway anatomy. (Reproduced with permission from Finucane and Santora [3])

Supraglottic Airway

The supraglottic airway (SGA) device – frequently refered to as a Laryngeal Mask Airway or LMA based on a commonly used commercial model – was first introduced in the United States in 1988 and FDA approved in 1991. The soft plastic device, seen in Fig. 9.5, has revolutionized the care of patients receiving general anesthesia and serves an alternative airway management device in

Fig. 9.5 Supraglottic airway. (Photo courtesy J. Ehrenfeld)

selected patients. Its use has largely supplanted the delivery of facemask anesthesia. During a difficult intubation, the insertion of an SGA can be lifesaving. Indeed, the most recent version of the American Society of Anesthesiologists Difficult Airway Algorithm (see Appendix A) places special significance on the use of the SGA as a rescue device when an anesthesiologist is unable to intubate and/or mask ventilate a patient.

The lubricated device is inserted blindly into a patient's mouth following the hard palate, past the tongue, and seated with the tip in the hypopharynx. The cuff is inflated isolating the gastrointestinal tract from the respiratory tract above the glottis. Multiple different forms of supraglottic airway devices have been developed during the past few decades. However, being supraglottic, the SGA does **not** protect against pulmonary aspiration to the same degree as an endotracheal tube. Other than for emergency ventilation, *relative* contraindications to the use of the SGA include:

- patients at increased risk for pulmonary aspiration
- patients or procedures requiring excessive positive pressure ventilation
- lengthy procedures
- procedures in any position other than supine

Direct Laryngoscopy and Tracheal Intubation

Direct laryngoscopy is the most common means of accomplishing endotracheal intubation. It is the process of visualizing a patient's glottis through his/her mouth by aligning the axes of the oral cavity, the pharynx, and the larynx as seen in Fig. 9.6.

Using direct laryngoscopy, endotracheal tubes are most commonly passed through the patient's mouth and into the glottis using a laryngoscope. A laryngoscope consists of a handle and an interchangeable blade with a light bulb on the end. The blades come in a variety of shapes and sizes, but the most commonly used are the Macintosh 3 (curved) and Miller 2 (straight) (see Fig. 9.7). Once the endotracheal tube passes through the glottis, a seal is formed between the endotracheal tube and the tracheal wall by inflating a cuff near the distal end of the tube with air. For intraoral procedures (such as the excision of a tongue lesion), endotracheal tubes can be placed into the glottis via a nasal approach utilizing either direct or fiber-optic laryngoscopy. Common errors in direct laryngoscopy include inserting the laryngoscope blade too deeply exposing the patient's esophagus or too superficially to expose the larynx, rocking the laryngoscope back on the upper incisor or upper lip instead of lifting the laryngoscope up and away from the laryngoscopist, and improperly sweeping the tongue from the line of sight.

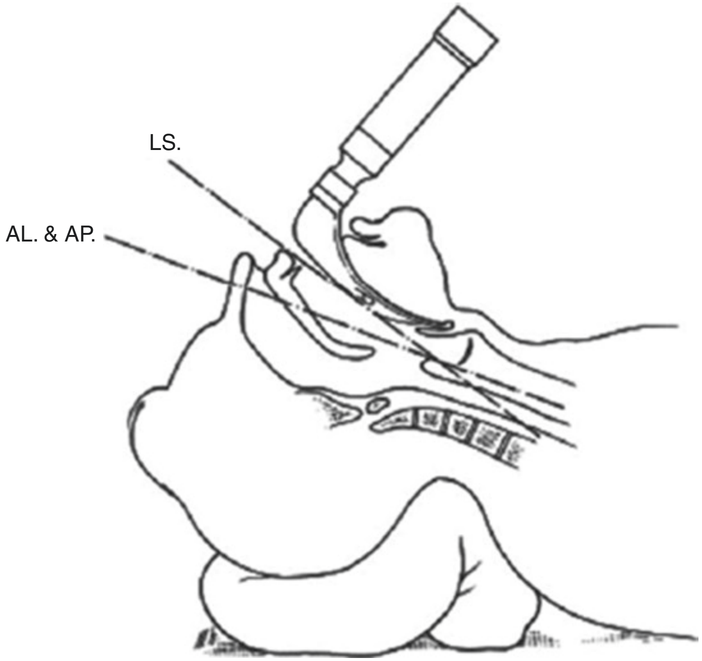

Fig. 9.6 Relationship of the oral, pharyngeal, and laryngeal axes for intubation. (Reproduced with permission from Ref. [3])

The placement of an endotracheal tube is considered the "gold standard" – the definitive airway management for two principal reasons. First, particularly with the placement of a cuffed endotracheal tube, the possibility of aspiration of gastric contents into the airways is greatly reduced. Second, it is via an endotracheal tube that a relatively greater positive pressure can be tolerated for optimal mechanical ventilation.

Fig. 9.7 Laryngoscopes: Macintosh and Miller blades. (Photo courtesy J. Ehrenfeld)

Rapid Sequence Induction

The reflux of gastric contents from the stomach into the distal airways via the glottis is a universal concern at all stages of anesthetic care. Fasting prior to elective surgery is the main intervention that guards against pulmonary aspiration. Risk factors for pulmonary aspiration may include:

- trauma patients
- patients undergoing emergency surgeries (fasting guidelines do not apply)
- pregnant patients
- patients with severe gastroesophageal reflux disease
- diabetics (decreased gastric emptying) or obese patients
- patients with neurological impairment

In order to decrease the interval between when a patient is awake with intact laryngeal muscles protecting their airway from aspiration and when the endotracheal tube is in place guarding against aspiration, a rapid sequence induction (RSI) may be performed. An RSI differs from a standard induction after the induction of general anesthesia in three ways:

1. During an RSI, face mask ventilation is **not used** to ventilate the patient. This is to avoid distension of the stomach with oxygen that can occur with facemask ventilation.
2. Cricoid pressure is maintained from before the time the patient receives induction agents until the endotracheal tube placement in the trachea is confirmed. The cricoid cartilage is the only tracheal cartilage that surrounds the entire trachea. Applying pressure to the anterior aspect of the cricoid cartilage occludes the esophagus by closing its lumen between the posterior aspect of the cricoid cartilage and the anterior aspect of the body of the cervical vertebrae.
3. Succinylcholine is classically used as the muscle relaxant of choice to facilitate intubation due to its short onset time. Rocuronium is another choice for patients who might have detrimental side effects from succinylcholine use (e.g. major burn and spinal cord injury patients, patients with personal of familial history of malignant hyperthermia, etc.).

During the coronavirus disease 2019 (COVID-19) pandemic, mask ventilation was avoided when possible, due to concern that it generated aerosols and thereby facilitated viral transmission. An

RSI technique was recommended and widely employed for endotracheal intubations during this time period.

Fiber-Optic Intubation

Endotracheal intubation can be accomplished via fiber-optic guidance. This is accomplished by passing the distal end of a bronchoscope through the glottis and then sliding an endotracheal tube off of the scope into the trachea under direct vision. Fiber-optic intubation can be accomplished in awake as well as anesthetized patients. Awake patients only tolerate the procedure with sufficient local anesthesia delivered to their airway beforehand via topicalization and/or nerve blockade. Sedation may be given to awake patients having fiber-optic intubation. Patients with anticipated difficult airways are often intubated using an awake fiber-optic technique.

Video Assisted Endotracheal Intubation (Glidescope, C-Trach, C-MAC, etc.)

There have been several airway management tools introduced that combine traditional laryngoscopy with fiber-optic or digital optical technology such as the Glidescope, C-Trach, or C-MAC. One of the benefits of these instruments is that they may allow intubation under conditions such as limited mouth opening that might have been more difficult or impossible with direct laryngoscopy. Video laryngoscopy has gained in popularity for airway management since its introduction because of its higher success rate for intubation on the first attempt, especially for management a potentially difficult airway. All training programs for airway management should offer comprehensive teaching for this potentially life-saving technology.

Evaluation and Management of the Difficult Airway

The ASA Difficult Airway Algorithm is a step-wise approach to managing a challenging airway (also see, Appendix A, ASA Difficult Airway Algorithm). The algorithm is designed to present a rational and safe approach to utilizing a number of different management techniques for securing the airway. These may include various types of equipment such as the intubating SGA, Lightwand, Combitube, and fiber-optic laryngoscope. Ultimately, if noninvasive attempts at airway management fail, options include waking the patient up or performing a surgical airway, such as cricothyroidotomy or tracheostomy.

Case Study

You are preparing to anesthetize a 50-year-old man for abdominal hernia repair with mesh. He is 68 in. tall and weighs 260 lb. He has a full beard and mustache. He has no other major comorbidities. He underwent general anesthesia 20-years-ago for arthroscopy of his knee and is not aware of any problems with the anesthetic. You are planning general endotracheal anesthesia.

What factors in this patient worry or reassure you regarding his airway management?

The patient is obese (BMI = 39.5). In itself, this is likely a risk factor for both difficult mask ventilation and difficult laryngoscopy. He also has a full beard, which can interfere with mask fit and make mask ventilation difficult. Conversely, he appears to have had an uncomplicated general anesthetic in the past. While reassuring, there are some caveats: his lack of awareness of problems does not mean that some did not occur but were not reported to the patient or recalled, and his physique may have been quite different 20 years ago.

How will you further assess his airway?

You will perform basic airway examinations on the patient. No one test is definitive, but most anesthesiologists use the Mallampati test, the thyromental distance, and a subjective assessment of neck mobility. Some use other tests as well, such as neck circumference (cut off >17 in. or 43 cm), ability to protrude the lower incisors anterior to the upper incisors, mouth opening, or sternomental distance. Each correlates somewhat with difficult intubation, but ultimately the judgment is likely more subjective and reflects the clinical gestalt of the experienced anesthesiologist.

You decide to proceed with induction of anesthesia. After administering propofol you attempt mask ventilation. You find it difficult to obtain a good mask fit and mask ventilation is difficult. How will you proceed?

You anticipated this problem preoperatively, so you have backup plans already in place. You can try an oral or nasal airway, which may reduce the pressure required to ventilate the patient by helping hold the upper airway patent. In some cases, using both may be helpful. You can also perform two-person ventilation, with one person holding the mask fit with both hands and the other ventilating by squeezing the reservoir bag. Finally, you can consider placement of an SGA to assist ventilation, or proceed directly with intubation.

You are now successfully ventilating the patient. You administer rocuronium to facilitate intubation. After ventilating the patient for 3 minutes, you perform direct laryngoscopy with a Macintosh 3 blade. You can only visualize the tip of the epiglottis. How wil you proceed?

As before, you have anticipated the possibility of this situation and have alternative plans in place for intubation, but you will not simply try again with the same technique: Plan B is not more of Plan A! A common initial step is to apply external laryngeal pressure either yourself, watching the laryngoscopic view as you do, or with a skilled assistant. In any difficult situation, consider calling for help early; it is better to ask for help and not need it than it is to be in trouble and unable to get it. Next, change the head position, laryngoscope blade, or operator. In obese patients, ramping the head of the bed, by putting several blankets under the shoulders, and more under the head (or using a specialized pillow such as the Troop elevation device), can potentially improve the view. A straight blade (Miller) can sometimes lift the epiglottis more efficiently than the curved (Macintosh) blade. Always ensure you have a good mask airway between efforts. No one ever died from lack of intubation per se, but lack of ventilation will kill! Use of the SGA, can be lifesaving if mask ventilation becomes impossible. This technique is now a standard part of the ASA Difficult Airway algorithm (see Appendix A).

Your initial efforts are still yielding only a view of the epiglottis. You decide to use an alternative airway device to assist you. What are some of your options?

In cases such as this, you can often successfully intubate the patient even without a view of the vocal cords. Some experienced anesthesiologists may attempt a blind pass of the stylet-angled endotracheal tube under the epiglottis. More frequently, an alternative device, such as the Bougie, is passed under the epiglottis first. One can often feel a clicking sensation as the tip brushes along the cartilage rings of the trachea. Then, an endotracheal tube can be passed over the Bougie into the trachea. Other options are to improve the view with different laryngoscopes. A video enhanced device, such as the GlideScope, Bullard laryngoscope, or C-Mac can display a better view than a conventional laryngoscope because of the integration of a camera or fiber-optic port on the distal aspect of the laryngoscope blade. Still another option is to use a flexible fiber-optic bronchoscope with an endotracheal tube threaded over it to locate the glottis. The endotracheal tube is then threaded off the bronchoscope into the trachea. Still other options include use of the SGA for the case, intubation through the

SGA with a fiber-optic technique or with the intubating SGA (which is specially adapted for passage of an endotracheal tube without the need for a fiber-optic scope), or even to awaken the patient and cancel the case. Note that with the FDA approval of sugammadex in 2015, you can rapidly reverse the neuromuscular blockade from an intubating dose of rocuronium. With the patient awake and spontaneously breathing, one can prepare for an awake fiberoptic intubation with local anesthetics employed for topicalization and/or nerve blocks of the airway.

For an alternative scenario, your surgical collegues tell you this is an emergent surgery due to an incarcerated abdominal hernia. How does this change your airway plan?

Due to the emergent nature of the surgery, the patient has likely not followed appropriate fasting guidelines for aspiration prevention, and regardless is at higher aspiration risk due to disruption of normal gut transit. For these reasons an RSI should be performed. Of note, a careful airway examination should *always* be performed. It is the anesthesiologistis responsibility to avoid the dangerous situation of encountering a difficult airway without appropriate backup plans and equipment – this is no less true for emergent surgery. Furthermore, it is generally prudent to use a technique that you are experienced with, rather than attempting something unfamiliar in an emergency situation. For this reason, trainees should gain experience in elective situations with as many different devices and techniques as possible.

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Suggested Further Reading

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