**ANESTHESIA FOR NOSE AND THROAT SURGERY Miller**

Functional Anatomy of the Larynx

The anesthesiologist confronted with decisions regarding airway management and difficult endotracheal intubations for patients with compromised airways must have a thorough knowledge of the physical and functional anatomy of the larynx. The larynx serves three functions: protection of the airway, respiration, and vocalization. 75, 76  The protective function occurs primarily through reflex and involuntary processes. The glottic closure reflex activated by swallowing is a basic primitive reflex elicited by many different sensory stimuli that affect the superior laryngeal nerve. The false vocal cords (ventricular folds) can act as a muscular valve that closes because of pressure from below to prevent egress of air. The true vocal cords constitute a one-way entrance valve that resists pressure from above but not from below. 75  Thus, during spasm of the true vocal cords, sudden positive pressure from above may not in itself be sufficient to move air into the lungs.

The nerve supply to the larynx occurs through the vagus nerve (the tenth cranial nerve). Sensory innervation is provided primarily by the superior laryngeal nerve, which arises from the inferior ganglion of the vagus. The internal branch of the superior laryngeal nerve consists mostly of sensory fibers; a few motor fibers lead to the arytenoid muscles. This internal branch further divides into upper and lower branches. The upper branch provides sensory innervation to the mucosa of the lower pharynx, both surfaces of the epiglottis, the vallecula arytenoepiglottic folds, and the laryngeal vestibule. The lower branch passes close under the surface of the mucosa of the pyriform fossa and supplies sensory innervation to the arytenoepiglottic folds and posterior rima glottidis. Sensory innervation below the true vocal cords and into the upper trachea is provided by the recurrent laryngeal nerves. Sensory innervation is denser at the glottic inlet, and there are more touch receptors at the lower half of the true vocal cords; in addition, the epiglottic and supraglottic area contain chemical and thermal receptors. 77  The sensory components of the internal superior laryngeal nerve also include joint, pressure, and stretch receptors from the intrinsic laryngeal muscles. The afferent response impulses from these receptors track back to the tractus solitarius of the brain stem. 75  The recurrent laryngeal nerves provide motor innervation to all the intrinsic laryngeal muscles, except the cricothyroid and inferior pharyngeal constrictors, which receive motor innervation from the external branch of the superior laryngeal nerve.

The intrinsic laryngeal muscles consist of the following:

1. Posterior cricoarytenoids abduct the vocal cords and widen the glottic chink during respiration.
2. Thyroarytenoids and lateral cricoarytenoids adduct the vocal fold (false cords).
3. Interarytenoids close the posterior gap in the glottis (posterior commissure) by abduction.
4. Cricothyroids adduct and tense the true vocal cords.
5. The vocalis muscle also shortens the true vocal cords.
6. Arytenoepiglottis and oblique arytenoids narrow the glottic inlet by adduction of the arytenoepiglottic folds.

The recurrent laryngeal nerve can be injured by endotracheal intubation, neck surgery, or stretching of the neck during surgery. The resulting tone and position of the vocal cords depend on whether the injury is unilateral or bilateral and on whether the external branch of the superior laryngeal nerve (the motor innervation of the cricothyroid muscle, which shortens the vocal cords) is also involved.

Unilateral recurrent laryngeal nerve injury causes the cord on the injured side to assume a paramedian position because the unopposed action of the ipsilateral cricothyroid muscle adducts the cord toward the injured side. If the external branch of the superior laryngeal nerve is also involved, the true vocal cord will be more medial and less tense. The voice is weak and hoarse, and the risk of aspiration increases. Eventually, the muscles compensate somewhat, and the cord becomes positioned more medially.

Laryngospasm

Laryngospasm is an exaggerated prolonged response of the protective glottic closure reflex, mediated by the superior laryngeal nerve in response to irritating glottic or supraglottic stimuli such as the presence of blood, food, vomitus, or a foreign body; instrumentation or manipulation of the endolarynx can all induce laryngospasm.

This strong glottic closure reflex can persist even after irritation of the mucosa ceases. 77  During a fully formed laryngospasm, the false cords and epiglottic body come together firmly. There is no air flow, no vocal sound, and the true vocal cords cannot be seen. The extrinsic muscles of the larynx (especially the thyroid) may also be involved to help create a muscular ball-valve mechanism.

Intravenous administration of lidocaine, topical application of cocaine, and deep levels of anesthesia attenuate the effect of the stimulus and the activity of the superior laryngeal nerve, thereby decreasing the likelihood of prolonged glottic closure. Incremental doses of intravenous fentanyl up to 200 mg depressed the protective airway cough reflex, but not the laryngospasm reflex. 78  Hypoxia and hypercarbia decrease postsynaptic potentials and brain-stem output to the superior laryngeal nerve, resulting in less vigorous glottic closure. 75  Thus, laryngospasm eventually ceases spontaneously as hypoxia and hypercarbia develop. Stimulation of the superior laryngeal nerve may also inhibit medullary inspiratory motoneurons, thereby decreasing phrenic nerve activity and causing a reflex apnea.

Head and Neck Surgery

Major surgery for cancer of the head or neck includes laryngectomy, radical neck dissection, hemimandibulectomy, and radical sinus surgery. Anesthesia management for surgery of malignant tumors of the larynx or pharynx was reviewed in detail by Morrison et al 76  and Daugherty. 79  Joseph et al 80  reviewed the complications and anesthesia considerations for head and neck and reconstructive surgery.

These patients are frequently heavy drinkers and smokers who have bronchitis, pulmonary emphysema, and/or cardiovascular disease. If the tumor interferes with eating, then weight loss, malnutrition, anemia, dehydration, and electrolyte imbalance can be significant. These patients are evaluated and treated as representing difficult endotracheal intubation and potential problems in airway management, as discussed later and in [Chapter 39](file:///Volumes/Anesthesia/site/content/v03/030570r00.htm) .

Generally, the use of an inhalation anesthetic dilates the bronchi, depresses airway reflexes, permits the use of high concentrations of oxygen, if necessary, and may produce moderate hypotension (systolic blood pressure 85–90 mm Hg). When a 10- to 15-degree head-up tilt is added, the resulting moderate hypotension may be sufficient to diminish blood loss without resorting to deliberately inducing hypotension. 57  Induced hypotension is not without risk in debilitated patients and may be unnecessary and dangerous 76, 81 [(Ch. 41](file:///Volumes/Anesthesia/site/content/v03/030620r00.htm)).

During radical lymph node dissection of the neck for carcinoma, manipulation of the carotid sinus may elicit a vagal reflex that causes bradycardia, hypotension, or even cardiac arrest. Furthermore, trauma to the right stellate ganglion and cervical autonomic nervous system during right radical neck surgery can prolong the QT interval and may lower the threshold for ventricular fibrillation. 82  Severe tachyarrhythmia and cardiac arrest have been reported in these cases, especially in association with hypokalemia.

Although venous air emboli are usually associated with neurosurgical procedures, open neck veins create the possibility of air emboli during head and neck surgery [(Ch. 52](file:///Volumes/Anesthesia/site/content/v04/040114r00.htm)). The incidence of air emboli during this type of surgery is low. An end-tidal CO2 monitor indicates a sudden fall in CO2 tension, and a precordial Doppler probe picks up the murmur characteristic of venous air embolism. Hypotension and arrhythmias are late signs of air emboli. 76  Treatment includes the following: increasing venous pressure (through the use of positive-pressure ventilation or jugular vein compression); slight Trendelenburg, left lateral positioning; discontinuation of N2O; use of 100 percent oxygen; and, if possible, aspiration of the air through a central venous catheter.

Postoperative considerations consist of care of the tracheostomy, use of humidified oxygen, institution of chest physical therapy, and the obtaining of a chest radiograph to eliminate the possibility of pneumothorax. The position of the tracheostomy tube should be checked, and possible subcutaneous emphysema and hematoma formation should be sought.

Thyroid Surgery

Perioperative complications of thyroid surgery include airway obstruction secondary to compressing hematoma, hypocalcemic tetany, and recurrent or superior laryngeal nerve paralysis. 80  The recurrent laryngeal nerve (RLN) is at risk for injury during thyroid and parathyroid surgery, resulting in vocal cord paralysis and even airway obstruction. The incidence of permanent nerve injury is 0.2 to 1.0 percent. 80  Spontaneous and evoked electromyography are used to monitor RLN function during surgery. 83  Nerve action potentials can be monitored using a carefully placed special Nerve Integrity Monitor (Xomed-Treace, Jacksonville, Fla) endotracheal tube 84, 85  or surface RLN postcricoid laryngeal electrodes. 86

Endoscopic Sinus Surgery

The complications of endoscopic sinus surgery are infrequent and are not usually related to the type of anesthesia. Venous air embolism, eye trauma, cerebrospinal fluid leak, excessive bleeding, 87  focal neurologic deficit, and death have been reported. 88

Trauma

Open and Closed Injuries to the Neck and Larynx

There is no classic or standard presentation of laryngeal trauma [(Ch. 62](file:///Volumes/Anesthesia/site/content/v04/040435r00.htm)). 89, 90, 91, 92  Often, internal damage is extensive but external signs are absent or only minimal (e.g., mild redness, minor lacerations, hematoma, or subcutaneous emphysema). Stridor and cyanosis may not be present. These injuries most often result from high-speed blunt trauma (motor vehicle accidents, gunshot wounds, or falls). For example, velocity-deceleration accidents can produce severe closed neck injury to the trachea and larynx. 92  Inertia carries the body forward, hyperextends the neck, and forces these vulnerable anterior cervical structures against the fixed cervical vertebrae. Tracheal damage can also be caused by a burst injury that produces simple tears, dislocation of arytenoid cartilages, disruption of the cricothyroid joint (causing a floppy vocal cord), and bleeding (leading to hematoma or edema in the paratracheal/arytenoepiglottic fold space). 92  Unfortunately, more obvious injuries such as a fractured femur can divert the physician‘s attention from the more subtle signs of airway problems (e.g., hoarseness, weak voice, or tracheal tugging).

The following signs of airway problems may be delayed: increasing stridor, wheezing, coughing, hemoptysis, retractions of the airway, changes in voice (loss of voice, hoarseness, weak voice), and difficulty in speaking or swallowing. Loss of neck prominences and increasing crepitus indicate torn mucosa in the trachea, pharynx, larynx, or esophagus. However, the amount of crepitus does not always correlate with the size of the tear.

An air leak can dissect into the paratracheal space and produce a pneumothorax. Such leakage increases with straining and application of positive-pressure ventilation. Regardless of size, all open neck injuries should be explored, because mortality is as high as 5 percent. Moreover, the possibility of a cervical spine fracture should always be considered when head or neck trauma has occurred.

A review of airway management in a known or suspected cervical spine injury indicated that early neck immobilization followed by orotracheal intubation, while an assistant applied in-line stabilization, had the lowest incidence of adverse events. There is no evidence that nasotracheal intubation is necessarily safer. 93

Certain age-related differences in anatomy may determine the type of injury and the ability to tolerate a compromised airway. The larynx of the infant and young child is positioned high in the neck and is shielded by the mandible. Cartilage is more elastic and flexible in the child, who is therefore less likely to sustain a fracture than is an adult. However, because of weaker connecting membranes, the child is more vulnerable to intercartilage rupture. 89  Moreover, because their airways have a small diameter at the subglottic region of the cricoid cartilage, young children do not tolerate edema or compromise of the airway as well as do adults.

There are many vital structures at risk in the neck (e.g., the recurrent laryngeal nerve, the carotid or inferior thyroid arteries, and major veins). Thus, mismanagement of neck and laryngeal injuries has the potential for acute disaster. Airway problems are dynamic. Mild stridor can worsen an air leak, aggravating subcutaneous emphysema and, in turn, increasing airway obstruction and stridor. The onset of cyanosis may be followed in rapid succession by myocardial ischemia, hypotension, hypercarbia, and loss of consciousness. Therefore, the anesthesiologist needs as much information as possible when attending to the problem airway. Monitoring of these patients from the emergency department to the operating room should include an ECG, pulse oximeter, and observation of the state of consciousness.

Blind passage of an endotracheal tube can increase damage or obstruction, induce laryngospasm, or create a false passage through a tear in the mucosa. Whenever possible, when dealing with laryngeal trauma, the trachea should be intubated under direct vision using a laryngoscope, rigid bronchoscope, or fiberoptic laryngoscope. A careful mask induction of anesthesia with no application of positive pressure, followed by bronchoscopic examination, may be safe in selected cooperative patients (i.e., those with no full stomach or bleeding in the airway). Tracheostomy using local anesthesia is frequently a safe approach to laryngeal trauma and is the only guarantee of establishing an airway when dealing with a possible laryngotracheal disruption.

Facial Injuries

The evaluation and anesthetic management 92, 94, 95  of maxillofacial injuries have been discussed extensively. The most common fractures involve the mandible and midface (Le Fort I, II, and III fractures of the maxilla). Because of the presence of loose teeth, blood, and displaced fragments, all these fractures may be accompanied by some degree of compromised airway. A first priority is to secure the airway by placing the patient in the lateral position, pulling the mandible or maxilla forward, and clearing the oropharynx of blood or loose teeth. If this action is not successful, endotracheal intubation or emergency tracheostomy should be considered. These patients may also have head trauma or fractures of the cervical spine.

Mandible fractures, if unilateral, remain stable. Bilateral mandibular fractures are unstable. The posterior fragment may be pulled medially and upward, causing the base of the tongue to obstruct the pharynx. Trismus and lingual hematoma or edema may contribute to respiratory obstruction. 92  If no trismus or mechanical problem exists, a routine rapid-sequence induction of anesthesia and tracheal intubation may proceed. Otherwise, induction of anesthesia with an inhaled anesthetic, or awake endotracheal intubation, is indicated. Although the possibility of interdental fixation may seem to make use of a nasotracheal tube preferable, the easiest route of intubation should be chosen. Later, during surgery, the oral tube can be removed and a nasal tube inserted. Patients undergoing interdental fixation should be given an antiemetic drug, undergo awake tracheal extubation, and be placed on their side with scissors/wire cutter at the bedside.

Midface fractures (Le Fort fractures of the maxilla) 92  often present difficult clinical problems. A Le Fort I fracture is a simple horizontal fracture of the lower maxilla that produces only a mobile palate. A Le Fort II fracture, a triangular extension of the Le Fort I fracture, involves two oblique fracture lines along the malarmaxillary suture to the floor of the orbit and the base of the tongue. The maxillae are displaced backward and may be free floating. The Le Fort III fracture is a high-level transverse fracture above the malar bone and through the orbits. It is characterized by complete separation of the maxilla from the craniofacial skeleton, epistaxis, and a flat dish-face deformity. Tears in the dura occur in 25 percent of all Le Fort II and III fractures, as evidenced by leakage of cerebrospinal fluid. Orotracheal intubation is necessary when intranasal damage is a possibility. Attempted passage of a nasogastric or nasotracheal tube may cause bleeding, mucosal dissections, and further damage. The course of these tubes is uncertain; they can enter the maxillary antrum, the orbit, the base of the skull, or even the cranium.

Special Clinical Problems Involving the Airway

Microlaryngoscopy

Many different anesthesia techniques have been advocated for microlaryngeal endoscopic surgery [(Ch. 39](file:///Volumes/Anesthesia/site/content/v03/030570r00.htm)). The common goal of these techniques is to provide the surgeon with a clear view, immobile field, and sufficient room in which to work. The anesthesiologist‘s objectives are to protect the trachea, to ensure good ventilation and oxygenation, to minimize secretions and reflexes, and to promote rapid awakening and return of protective airway reflexes. Morrison et al 76  described the advantages and disadvantages of these techniques.

Because of the varying degrees of upper airway disorder and the need for rapid awakening in these brief (30–40 min) procedures, routine premedication should be avoided. An antisialogogue, such as glycopyrrolate, which facilitates drying of oral secretions, may be helpful. If sedation is necessary to decrease anxiety, intravenous titration of 1-mg increments of a benzodiazepine such as midazolam may be given with monitoring in the preinduction area.

Special attention must be devoted to understanding the extent of the upper airway disorder that brings these patients to surgery. For example, preoperative decisions about tracheal intubation and anesthesia management depend on whether the abnormality is a small lesion (e.g., a vocal cord polyp or carcinoma *in situ* ), a large and potentially obstructing lesion such as a papillomatosis, or a large and friable supraglottic tumor that will completely obstruct the glottic opening. If there is any question about the airway, direct laryngoscopic examination should be performed (after topical laryngeal block) 96, 97  in the awake patient to assess the difficulty of intubation.

In only approximately 5 percent of microsurgical procedures on the larynx do the pathologic conditions involve the lower third of the vocal cords or the posterior commissure area. Therefore, for 95 percent of these procedures, a small, long (5 mm × 31 cm) endotracheal tube having a highvolume low-pressure cuff can be used without obscuring the surgeon‘s view. 76, 98  The posterior commissure area may then be inspected at extubation or by moving the tube aside. Adequate oxygenation and ventilation can be monitored in adults by controlled ventilation through a small (4.5–5.0-mm ID) endotracheal tube. 99  The use of a small endotracheal tube allows for application of positive-pressure ventilation, ensures the absence of gastric distention, facilitates control of oxygenation and elimination of CO2, protects the trachea, and allows for a variety of general anesthesia regimens and an indefinite time period for the surgeon.

Another method of providing anesthesia for microlaryngoscopy places a small catheter between the vocal cords for insufflation of anesthetic gases at high flows. This technique does not protect the trachea or allow for use of positive-pressure ventilation. High concentrations of the inhaled anesthetic must be used to overcome atmospheric dilution, and, unfortunately, exhaled gas is blown back at the surgeon and into the operating room. There may also be motion of the vocal cords.

Jet ventilation using the Venturi entrainment effect provides anesthesia and ventilation without the use of an endotracheal tube. 76, 100  The surgeon has an unobstructed view of the larynx. Keeping the tip of the jet within the laryngoscope avoids airway barotrauma and provides a clear view. Alignment of the laryngoscope with the tracheal axis is essential. The vocal cords need to be relaxed fully, and pathologic conditions in the airway must not be so large as to obstruct airflow into the trachea. The jetted gas must have free egress, and motion of the chest wall must be monitored at all times. Ventilation begins at low pressures (30–50 psi). Inspiration is 1.5 seconds, passive expiration is 6 seconds, and ventilatory rate is 6 to 7 breaths/min. 76  The jet Venturi technique is contraindicated in children, obese patients, and patients with bullous emphysema. When large tumors are present in the upper airway, debulking of the tumor using general anesthesia and a tracheal tube should be accomplished first, 76  because the jet technique may force blood or tumor tissue into the lungs and gas into the stomach.

An apneic technique using alternate tracheal intubation and no tube during endoscopic removal of papillomas in children has been used successfully by Weisberger and Miner. 101  Moreover, Babinski et al 102  described the use of high-frequency positive-pressure ventilation during anesthesia for laryngoscopy. Small tidal volumes provide good gas exchange at low airway pressures. Respiratory rates of 60 breaths/min at 60 to 100 psi are used by means of a stiff 3.5–4.0-mm catheter placed through the vocal cords. The risk of barotrauma and pneumothorax is lower, especially in patients with obstructive airway disease.

Good muscle relaxation is an essential part of anesthesia management for microsurgery of the larynx. A succinylcholine drip infusion may be considered for very brief cases. If the procedure is expected to last at least 30 minutes, use of a neuromuscular blocking drug such as vecuronium, rocuronium, or mivacurium for tracheal intubation allows return of muscle strength and spontaneous respiration for safe extubation.

Stimulation of the larynx can induce many reflex responses that produce hypertension, tachycardia, and arrhythmias. Intravenous administration or topical application of lidocaine and small doses of fentanyl (1–2 mg/kg IV) will help to moderate the sympathetic response. b-Adrenergic receptor blocking drugs may also be helpful.

Propofol induction (2 mg/kg IV) and infusion (10 mg/kg/h) combined with fentanyl (1–2 mg/kg IV) supplementation, topical anesthesia of the larynx, and appropriate muscle relaxation have been used for microlaryngoscopy procedures. 103  Monitoring (pulse oximeter, ECG, blood pressure, and end-tidal concentrations of CO2 ) is especially important, because the incidence of myocardial infarction or ischemia after microlaryngoscopic procedures has been reported to be 1.5 to 4.0 percent. 104

Laser Surgery of the Upper Airway

CO2 and neodymium–yttrium aluminum garnet (Nd:YAG) lasers are frequently used for microsurgery of the upper airway and trachea [(Ch. 64](file:///Volumes/Anesthesia/site/content/v04/040482r00.htm)). The surgical advantages of using lasers include less bleeding, the ability to coagulate small vessels, maintenance of sterile conditions, less tissue reaction, increased precision of dissection, preservation of normal tissue, and, in the case of Nd:YAG lasers, the ability to transmit the beam by fiberoptics. Excellent articles by Van der Spek et al 105  and Hermens et al 106  reviewed the physics and medical uses of lasers, including safety and implications for anesthesia management.

The American Society for Testing and Material (ASTM) Subcommittee F29.02.10 of the Anesthesia Patient Safety Foundation developed guidelines for the provision of safe anesthesia during laser surgery for the upper airway. These guidelines compare and comment on the advantages and disadvantages of several anesthetic techniques and laserresistant endotracheal tubes. 107

Light amplification by stimulated emission of radiation (LASER) produces a beam of light that is monochromatic (of the same wavelength) and “coherent” (all the photons are moving in the same direction). Lasers exist in the infrared, visible, and ultraviolet regions of the electromagnetic spectrum. Depending on the emission medium used, such light can be focused into an extremely small point, thereby achieving a very high-power density. This beam of high-power density is capable of vaporizing biologic tissue. Each laser medium emits radiation of a specific wavelength, which determines how the beam will interact with biologic tissue. Lasers are operated in short pulses, long pulses, or continuously. The continuous-wave CO2 laser, which produces radiation having a wavelength of 10 mm, is strongly absorbed by water, damaging tissue surfaces to a depth of 200 mm. For this reason, the CO2 laser is suitable for removing lesions on the vocal cords and in the larynx.

The Nd:YAG laser, a short-pulsed, high-powered glass laser producing light with a wavelength of 1.06 m, can be transmitted by fiberoptics. Energy from Nd:YAG or argon (wavelength of 0.5 mm) lasers is absorbed preferentially by hemoglobin and pigmented tissue, has deep, penetrating effects, and is useful in treating detached retinas.

Reflection and scatter of laser beams can cause immediate or delayed injury (perforation, hemorrhage, pneumothorax) to normal tissue. The CO2 laser reacts at the surface, causing corneal damage, whereas lasers of shorter wavelength (argon, Nd:YAG) can pass through the cornea and damage the retina. Therefore, the patient‘s eyes must be taped closed and covered with moist gauze. Nontarget tissue should be protected by moist gauze covering; in addition, alignment of the laser should be checked, and immobility of the patient should be ensured. Operating room personnel should wear appropriately colored glasses or goggles to absorb the wavelength emitted by the laser in use. Laser hits on the skin cause a pinpoint burn. Instruments used with lasers should have a dull matte finish, to decrease reflection. The energy density of reflected beams decreases greatly as the distance from the focal point increases.

Fire is a major hazard. As a source of intense heat, lasers can ignite various materials used in anesthesia practice (endotracheal tubes). The CO2 laser beam can penetrate an endotracheal tube and ignite a fire, which would then be supported by oxygen and N2O. 108, 109  The subglottic, epiglottic, and oropharyngeal areas are the regions usually involved. Furthermore, inhalation of smoke can cause chemical injury, bronchospasm, edema, and respiratory failure. Red rubber tubes char, melt, and then burn, producing carbon monoxide gas. Polyvinyl chloride tubes burn more vigorously, producing hydrogen chloride, a pulmonary toxin.

In 1979, the reported incidence of airway fires during CO2 laser surgery was 0.4 percent. 106, 110  However, with the use of modern equipment, techniques, and gas mixtures according to the Anesthesia Patient Safety Foundation guidelines for anesthesia for laser surgery, 107  the incidence of airway fires during laser surgery should be negligible.

To reduce the hazard of fire during laser surgery on the airway, not more than 30 percent oxygen in nitrogen or helium should be used in the gas mixture. N2O supports combustion, as does oxygen. Sixty percent helium is an effective fire quencher if the CO2 laser is used at an energy level of 10 watts or less. 111  The use of selected, protected endotracheal tubes reduces the risk of fire. 112  Commercially available laser-safe endotracheal tubes should be used. These may be metal, aluminum, or copper foil 113 –wrapped, laser-resistant materials 114  or double-cuffed silicone-coated metal tubes. These tubes may be recommended as resistant to the CO2 laser but not to the Nd:YAG laser. 115

An alternative is to use a Venturi ventilation technique with no endotracheal tube. 100  However, fire in the airway can still be a risk, because tissue may dry up, carbonize, and ignite in the high jet flow of oxygen.

Treatment of airway fires requires temporary discontinuation of oxygen, removal of the burning endotracheal tube, reintubation of the trachea, and flushing of the pharynx with cold saline. Later, a rigid bronchoscope should be used to check for damage and the presence of foreign bodies (e.g., pieces of burned tube). Administration of humidified gas, steroids, and antibiotics, the use of controlled ventilation, and even tracheostomy may be necessary. Monitoring includes the use of chest radiographs, pulse oximetry, ECG, and analysis of arterial blood gases [(Ch. 64](file:///Volumes/Anesthesia/site/content/v04/040482r00.htm)).

Laser surgery of the tracheobronchial tree is performed with CO2 or Nd:YAG lasers by means of a rigid bronchoscope. This instrument allows better visualization, access, control of bleeding, suctioning, and irrigation. 116  The literature on ventilation and anesthesia technique for bronchoscopic laser surgery is not consistent. Reviewing many techniques, Van der Spek et al 105  discussed advantages and disadvantages and described their own successful clinical practices.

The management of subglottic laser surgery presents challenges for the anesthesiologist. Bargainner et al 117  analyzed these challenges and outlined safe methods using a ventilating laryngoscope and jet ventilation, as well as discussing potential complications [(Ch. 68](file:///Volumes/Anesthesia/site/content/v04/040608r00.htm)).

Either a CO2 laser or an Nd:YAG laser is used in subglottic laser surgery. The Nd:YAG laser penetrates tissue (4–5 mm), has hemostatic properties, and can be conducted by a single optic fiber. Even foil-wrapped and special laser-shielded endotracheal tubes have been perforated and ignited within 12 seconds during continuous Nd:YAG laser exposure. 118

Postoperative considerations include head-up positioning to decrease edema, careful observation for bleeding and edema, and administration of humidified oxygen. If a Venturi jet technique has been used, complications such as pneumothorax or respiratory failure (from the forcing of blood or tissue particles into air passages) may occur within the first 2 hours. Steroids and racemic epinephrine mist may be helpful in controlling laryngeal edema.

Tonsillectomy

Improved monitoring and postanesthesia care have reduced mortality from tonsillectomy to almost zero [(Ch. 59](file:///Volumes/Anesthesia/site/content/v04/040356r00.htm)). However, management of the airway during this procedure can still present a challenge to the anesthesiologist. The goal of anesthesia for elective tonsillectomy is to provide deep general anesthesia that prevents reflex-induced hypertension, tachycardia, or arrhythmias. Muscle relaxation is required to allow easy placement of the mouth gag and to prevent bucking, coughing, or straining. Rapid recovery to consciousness and the return of protective airway reflexes are also desirable. The safest practice is probably to extubate the trachea when the patient is awake. The use of the reinforced, flexible laryngeal mask airway for tonsillectomies, 119, 120, 121  adenoidectomies, 122  and nasal surgery 123  provides excellent airway protection and good field exposure with less eventful recovery, cough, or airway obstruction on emergence.

Postextubation stridor and laryngospasm following adenotonsillectomy can be minimized by applying topical 2 percent lidocaine (maximum 3 mg/kg) to the glottic and supraglottic areas before intubation. This proved as effective as giving intravenous lidocaine (1 mg/kg) just prior to extubation, but without higher sedation scores. 124

Preoperative evaluation includes checking for loose teeth (especially in the 4- to 7-year-old patient), ensuring there has been no recent ingestion of aspirin, and determining coagulation variables. Premedication is usually not necessary. Barbiturates are of little use in brief upper airway surgical procedures, which require rapid return of protective airway reflexes and may render the larynx more susceptible to laryngospasm during a slow awakening from the effects of barbiturates.

A technique using fentanyl and a short-acting muscle relaxant with a volatile inhaled anesthetic is satisfactory. A topical spray of 4 percent lidocaine on the tonsil area will help to decrease the anesthetic requirement, the incidence of arrhythmias, and postoperative stridor and laryngospasm. 124, 125  These patients should be well hydrated with a solution of balanced crystalloid (3–5 mL/kg/h). Blood loss during tonsillectomy is difficult to estimate and may reach 5 percent of estimated blood volume. Blood loss should be replaced if it exceeds 10 to 15 percent of blood volume.

Patients with sickle cell disease are at a higher risk for postoperative complications such as pneumonia, atelectasis, and vaso-occlusive crises. Children with sickle cell disease presenting for elective tonsillectomy should be given a transfusion to reduce the hemoglobin S ratio to less than 40 percent. 126  Children with chronic adenotonsillar hypertrophy may also have associated undiagnosed obstructive sleep apnea syndrome and are at increased risk for respiratory complication in the immediate recovery period. 127  Patients with Down syndrome may have large tongues and unstable atlanto-occipital joints and require more careful perioperative airway management for tonsillectomy. 128

Tracheal extubation usually occurs in the operating room when the patient is awake and protective airway reflexes are present. Some coughing should not interfere with surgical closure of the tonsillar bed. Intravenous administration of lidocaine (1.5 mg/kg) has been used to decrease laryngospasm after extubation.

Pediatric tonsil patients are placed in the “tonsil position” (i.e., on one side, with the head slightly down) in the recovery area to allow blood or secretions to drain out rather than flow back onto the vocal cords and are observed closely for bleeding or airway obstruction. One hundred percent oxygen mist is given by facemask; pulse oximeter, arterial blood pressure, and ECG are monitored routinely. Patients should be kept in the recovery room for at least 60 minutes; the pharynx should be rechecked directly for bleeding before discharge from the recovery room.

Intraoperative complications from tonsillectomy consist of arrhythmias caused by increased levels of endogenous epinephrine from light general anesthesia, sensitization of the myocardium to catecholamines by halothane, and perhaps hypercarbia. Postoperative complications consist of poor respiratory function and continued bleeding. Patients with a history of obstructive sleep apnea must be extubated awake and observed closely in the recovery room for depressed respiratory function or apneic periods. 129, 130

Increasingly, tonsillectomy is being performed as an outpatient procedure. Although postoperative bleeding is the most serious complication, persistent vomiting and poor oral intake are the most common reasons for unscheduled overnight admission after ambulatory surgery. The incidence of PONV can be as high as 70 percent during the first 24 hours after tonsillectomy. 131  Many different antiemetic regimens have been advocated to minimize PONV following tonsillectomy surgery. 132, 133, 134  Pappas et al 135  noted that a single, large (1 mg/kg, maximum 25 mg) preoperative dose of dexamethasone significantly decreased the incidence of PONV after tonsillectomy in children.

Although metoclopramide may help to empty the stomach, it does not seem to have specific antiemetic properties compared with ondansetron in preventing PONV after tonsillectomy. 136  Withholding oral fluids postoperatively from children undergoing day surgery reduces the incidence of vomiting. 137

It is important to develop anesthetic techniques and to use appropriate antiemetics and recovery protocol to minimize vomiting after tonsillectomy (e.g., avoid meperidine, decompress stomach of air and blood, discontinue N2O, 138  administer an antiemetic regimen prophylactically, keep patient well hydrated intravenously, and do not force oral food or fluid intake). 137

Bleeding Tonsil Management

The incidence of post-tonsillectomy bleeding that requires surgery is 0.3 to 0.6 percent. This complication usually occurs within 6 hours of surgery 139  and can be a difficult anesthesia problem. Management of anesthesia for these patients should include the following considerations. The extent of blood loss may not be obvious and is usually underestimated. Before the patient is transported to the operating room, no premedication should be given, and coagulation variables should be checked, if possible. Moreover, blood should be typed and crossmatched for blood replacement, and the patient should be well hydrated via a reliable intravenous line. Most problems before induction of anesthesia for bleeding tonsil are caused by unsuspected hypo-volemia, full stomach, and airway obstruction.

At induction of anesthesia, an additional person should be available to provide good suctioning of blood. A rapid-sequence induction of anesthesia with application of cricoid pressure and slight head-down positioning of the patient will protect the trachea and glottis from aspiration of blood. After induction, a nasogastric tube may be placed and removed. As with elective tonsillectomy, extubation is safest with the patient awake.

Abscesses

A peritonsillar abscess extending to the soft palate can cause severe pain, trismus, dysphagia, and respiratory obstruction. Often, the abscess can be drained or decompressed by incision or needle aspiration using local anesthesia. The risks of general anesthesia include further respiratory obstruction, difficult endotracheal intubation because of continued trismus and distorted anatomy, and spontaneous rupture of the abscess, with subsequent spilling of pus into an unprotected airway.

Planning general anesthesia for a peritonsillar abscess may include preoperative decompression of the abscess by needle aspiration to minimize the risk of rupture. A difficult intubation should be expected because of distorted anatomy, edema, and incomplete resolution of trismus. Although difficult, endotracheal intubation must be performed slowly, carefully, and gently. If the abscess is right-sided, a left-sided approach for laryngoscopy may be indicated. If airway obstruction is expected, one of three options should be selected: careful intubation of the trachea under direct vision, with the patient awake; induction of anesthesia by mask, with the patient breathing spontaneously; or elective tracheostomy.

Ludwig angina is a cellulitis of the submandibular and sublingual spaces that may include the floor of the mouth and anterior compartments of the neck. Visualization of the glottic opening is frequently impossible because of trismus, edema, and distorted anatomy. General anesthesia is contraindicated if stridor occurs at rest. Therefore, tracheostomy using local anesthesia through the cellulitis, although not ideal, may be the safest way to secure the airway.

Adult Epiglottitis

Adult epiglottitis occurs in 1 per 100,000 adults per year. 140  Causes include infection, trauma, and radiation. Symptoms are typically sore throat, dysphagia, a muffled “hot potato” voice and respiratory distress. This respiratory distress can be immediate, severe, and progress rapidly, requiring airway management in the operating room. A careful inhalation induction and titrated intravenous sedation prior to a rigid bronchoscopy or endotracheal intubation are the recommended techniques. 141, 142  The use of steroids is controversial, but it may help in cases of angioedema. 143  Racemic epinephrine is not necessarily useful.

Foreign Body in the Airway

Aspiration of a foreign body into the trachea is a common cause of sudden onset of obstructive breathing, croupy cough, hoarseness, or wheezing in young children. Several reviews have described in detail the problems and precautions of managing anesthesia during retrieval of a foreign body from air passages. 76, 95  Care must be taken not to convert partial obstruction into total obstruction by dislodging the foreign body into the upper trachea.

During severe airway obstruction, the anesthesiologist should consider either direct laryngoscopy in an awake patient or a rigid bronchoscopic examination without application of positive pressure. Most of these cases occur in children. Usually, a gentle mask induction without cricoid pressure or positive-pressure ventilation is the preferred induction technique, 144, 145  although Kosloske 146  routinely used muscle paralysis and controlled ventilation. Removal of foreign bodies from the trachea and larynx is a hazardous procedure. The surgeon must be prepared to perform an emergency tracheostomy or cricothyrotomy if partial obstruction suddenly becomes complete.

Laryngeal and subglottic edema may last for 24 hours after removal of a foreign body. Close observation and use of humidified oxygen are suggested during this recovery period.

Difficult Airways: Causes and Classification

Difficult airways include both difficult intubations and compromised airways [(Ch. 39](file:///Volumes/Anesthesia/site/content/v03/030570r00.htm)). Difficult intubations are usually caused by anatomic abnormalities such as micrognathia, limited jaw motion, or congenital syndromes (craniofacial dysostoses). Other causes of difficult intubations include obesity, acromegaly, cervical spine problems, rheumatoid arthritis, and even gastric reflux. 147  These patients usually have intact, clear airways, but abnormal anatomy prevents adequate visualization of the glottis and may inhibit easy passage of an endotracheal tube.

A preoperative evaluation of the head, neck, mandible, tongue, teeth, and oropharynx using specific assessment techniques may help to predict a potentially difficult intuba-tion. Various strategies have been devised and modified to assess the airway. 148, 149, 150, 151, 152  They often have a high sensitivity, but low predictive value, and may fail to predict difficult intubations accurately. Compromised airway implies partial obstruction to air flow and the risk of total obstruction if tumor, infection, or disease further narrows the airway. Pathologic conditions above the glottis may prevent a clear view of the glottic opening, whereas subglottic lesions permit a good view of the vocal cords, but they require careful placement of a small endotracheal tube or bronchoscope. All compromised airways are difficult intubations, but not all difficult intubations are in patients with compromised airways. A large percentage of serious anesthesia accidents involves some aspect of airway mismanagement. Caplan et al 153  reported that the majority of respiratory complications involve inability to intubate, unrecognized esophageal intubation, or inadequate ventilation. The American Society of Anesthesiologists (ASA) developed a specific practice algorithm for safe management of the difficult airway. 154  Several reviews of the causes, techniques, necessary equipment, and problems associated with difficult airways are available. 155  Benumof 154, 158  reviewed the specific management of the difficult adult airway with emphasis on awake tracheal intubation techniques 96  and the use of transtracheal jet ventilation (TTJV). 159  The intubating laryngeal mask airway 160, 161, 162  is a recent development. Benumof noted that the incidence of “cannot ventilate–cannot intubate” situations may be as high as 1 per 5,000 anesthesics. 158  Proper responses to these emergency situations involve use of the intubating laryngeal mask airway, Combitube (Kendall-Sheridan, Argyle, NY), TTJV, or immediate surgical tracheostomy. 154  Sofferman et al 163  discussed alternatives for management of lost airway during anesthesia inductions in head and neck surgery, including use of the laryngeal mask airway and Combitube. A combined technique using an anterior commissure laryngoscope and gum elastic bougie is preferred for the special circumstances of patients requiring otolaryngologic surgery.

Laryngeal Block

Topical and regional nerve blocks of the nasal oropharynx, larynx, and glottis may be used to facilitate awake endotracheal intubation(Chs. [39](file:///Volumes/Anesthesia/site/content/v03/030570r00.htm) and [43](file:///Volumes/Anesthesia/site/content/v03/030658r00.htm)). Sanchez et al 96  and Donlon 97  reviewed in detail the preparation of patients for awake intubation, including premedication, topicalization techniques, and specific nerve blocks from nasal cavity to trachea. These include sphenopalatine nerve and blocks of the glossopharyngeal and superior laryngeal nerves. 96, 156, 164, 165  The glossopharyngeal nerve (the ninth cranial nerve) supplies sensory innervation for the posterior third of the tongue, the oropharynx, the tonsillar area, and the gag reflex. This nerve can be blocked by infiltration of 3 mL of 2 percent lidocaine posterior to the palatopharyngeal fold at its midpoint, 1 cm deep to the mucosa of the lateral pharyngeal wall. Paralysis of the pharyngeal muscles and relaxation of the base of the tongue may cause some respiratory obstruction. 166, 167  Therefore, if a glossopharyngeal nerve block is used with blockade of the superior laryngeal nerve for awake intubation, the latter procedure should be performed first to avoid respiratory obstruction.

The internal branch of the superior laryngeal nerve lies just below the mucosa in the depth of the pyriform fossa. A topical block of this nerve can be performed by applying local anesthetic for 3 to 5 minutes onto the pyriform fossa mucosa. 96

In the absence of neck tumor or infection, an external approach to block the superior laryngeal nerve may be used. A 23-gauge needle is placed 1 cm medial to the superior cornu of the hyoid bone and is directed caudad to pierce the thyrohyoid membrane. After aspiration, 2 mL of local anesthetic is injected. Block of the superior laryngeal nerve anesthetizes all laryngeal mucous membranes above the rima glottidis, including epiglottic and arytenoepiglottic folds. Because it removes some protective reflexes, this block should be used with caution in patients with a full stomach. A maxillary nerve block can interrupt sensory innervation to the nasal cavity in preparation for nasotracheal intubation. The mandibular nerve can be blocked from an external approach. This block eliminates masseter muscle tone, relaxes the jaw, and minimizes biting by an awake but uncooperative patient. The loss of masseter tone may cause partial upper airway obstruction.

The trachea and vocal cord area can be anesthetized either by atomizer from above or by transtracheal injection. The sensory innervation is supplied by the vagus nerve via the RLN. These nerves run along the tracheoesophageal groove and supply both sensory fibers and motor fibers (intrinsic muscles of larynx). Bilateral, specific RLN blocks could result in bilateral vocal cord paralysis and airway obstruction.

A combination of these regional blocks used in conjunction with topical anesthesia of the pharynx and larynx is simple and often very effective in dealing with difficult tracheal intubations or compromised airways. 51  Direct laryngoscopy, bronchoscopy, or tracheal intubation can be performed in the awake patient with minimal discomfort or risk after a topical laryngeal block. Lidocaine is absorbed rapidly into the systemic circulation from the trachea; therefore, the maximum safe dose of topical lidocaine in the trachea is 4 mg/kg.

Management Techniques: Difficult Intubations

These situations can occur unexpectedly in otherwise healthy patients, despite preoperative airway evaluation, and they usually involve the inability to visualize the glottic opening or even the epiglottis. Crosby et al 155  reviewed the literature and made recommendations for the safe management of unexpected difficult airways. Parmet et al 168  found that, over a 2-year period, the laryngeal mask airway provided rescue ventilation without complications in 94 percent of cases of unanticipated difficult intubation and ventilation. Difficult direct laryngoscopy occurs in 1.5 to 8.5 percent of general anesthetics. Failed intubation occurs in 0.13 to 0.3 percent of general anesthetics. 155  Current techniques for predicting difficult intubations have a low predictive value. Simple initial methods for dealing with these unexpected situations include the following: manipulation of the cricoid cartilage by the optimal external laryngeal manipulation 169  or backward, upward, rightward laryngeal displacement 170  maneuver to bring the glottis into view; use of a stylet in the endotracheal tube; repositioning of the head in a more-or-less flexed position; change (in size or shape) of the laryngoscope blade; and use of special blades. 171  A flexion-flexion (chin to chest) position of the head and neck may be ideally suited to achieve optimal glottal exposure in cases of difficult direct laryngoscopic intubations. The flexion-flexion position aligns the oral and pharyngeal cavities to facilitate direct view of the vocal cords. Extension of the head at the atlanto-occipital joint leads to backward displacement of the tongue base into the airway. If these actions are ineffective, further options include the intubating laryngeal mask airway, 154, 160, 162, 172  use of a flexible fiberoptic scope, various rigid fiberoptic laryngoscopes, 173, 174  or nasotracheal intubation with general anesthesia, spontaneous respiration, and as much visualization of the mouth as possible. Fewer than 50 percent of blind nasotracheal intubations succeed on the first attempt. Furthermore, bleeding and trauma often occur after several attempts.

Other methods use a light wand, 175, 176  a rigid bronchoscope, Combitube, 177  or a retrograde catheter technique. 171, 175  The Combitube has been associated with esophageal rupture and should be inserted carefully, under direct vision whenever possible. 178  Practice and skill should be attained in routine cases before relying on these methods for a difficult intubation. Fiberoptic equipment must be used often enough in routine situations to be reliable during intubation of abnormal airways. 179, 180  The fiberoptic scope has been useful during nasotracheal intubations in rheumatoid arthritis patients who have trismus or spondylosis. Fiberoptic visualization may also be difficult when the larynx has pathologic conditions or abnormal supraglottic anatomy. [Chapter 39](file:///Volumes/Anesthesia/site/content/v03/030570r00.htm) also discusses difficult endotracheal intubations.

Compromised Airway

Several investigators have provided guidelines for the safe evaluation and management of patients with compromised airways. 92, 154, 155, 156, 157, 158, 171, 172, 181, 182  Often, the extent of the limitation of airflow is not obvious. Although clinical signs and symptoms (stridor, tachypnea, cyanosis, anxiety, sternal retractions, diaphoresis, and tachycardia) are usually present, patients with chronically abnormal airways learn to adapt their breathing and vocalization to limited airflow. Before attempting any method of intubating the compromised airway, as much information as possible should be gathered concerning the airway problem. Such information consists of radiographs, CT, or magnetic resonance imaging (MRI) scans, old records, history, and physical examinations.

Unlike difficult intubations in normal airways, patients with compromised airways must not be given general anesthesia or muscle relaxants unless control of the airway is ensured. Attempts at awake intubation should not be done “blindly” in patients with uncertain pathologic processes. Safe techniques for managing compromised airways include awake direct laryngoscopy after careful topical laryngeal block 96, 97  ; spontaneous breathing using an inhaled anesthetic; awake fiberoptic evaluation of the airway 183 ; tracheostomy under local anesthesia; and, if necessary, lifesaving TTJV through a cricothyroid puncture with a large-caliber (14-gauge) needle, or an emergency cricothyrotomy. 184

The efficacy and importance of TTJV in the management of the difficult airway were reviewed by Benumof. 159, 185  Inadequate oxygenation and ventilation were reported to be responsible for as many as 75 percent of cardiac arrests following the administration of anesthesia. TTJV is a quick, easy, safe solution to the problem of “cannot ventilate/ intubate.” Various methods of providing TTJV are possible, and it is recommended that TTJV be available for every anesthetizing location. The incidence of serious complications resulting from elective use of TTJV is relatively low and is usually related to tissue emphysema or pneumothorax. The risk of barotrauma, gas trapping, and lung hyperexpansion from TTJV is greatly increased in cases in which total upper airway obstruction limits the ability to expel TTJV gas from the lungs. 159

Emergency Tracheostomy

Tracheostomy may be necessary for upper airway obstruction caused by marked edema, large supraglottic tumors, laryngeal trauma, or impacted foreign bodies, as well as for loss of protective airway reflexes owing to muscle weakness, unconsciousness, or chronic aspiration caused by vocal cord paralysis(Chs. [62](file:///Volumes/Anesthesia/site/content/v04/040435r00.htm) and [72](file:///Volumes/Anesthesia/site/content/v05/050015r00.htm)). 186  Other reasons for tracheostomy are that endotracheal intubation is not feasible, stridor is present at rest, patency of the airway is lost on attempts to induce anesthesia by mask, or an unstable foreign body is present in the airway. Moreover, a tracheostomy after major head and neck surgery sometimes ensures a smoother postoperative recovery.

Ideally, a tracheostomy performed using general anesthesia provides the surgeon with an immobile, cooperative patient and allows a less-hurried procedure. When possible, general anesthesia may be provided by means of a small endotracheal tube, a rigid bronchoscope, a facemask, a glottic aperture seal airway, or a laryngeal mask airway. 187  Intubation may be accomplished with the aid of a fiberoptic bronchoscope or an intubating laryngeal mask airway. An expectation of airway obstruction warrants consideration of avoidance of muscle relaxants. Careful direct laryngoscopy with the patient awake may be possible to evaluate the airway fully before deciding a safe course of action.

Tracheostomy using local anesthesia is safe but requires some patient cooperation. Infiltration of local anesthetic may be supplemented with a bilateral superficial cervical plexus block. Patient cooperation is best achieved through the anesthetist‘s confident demeanor and verbal reassurance, and not through heavy sedation of the patient. During the procedure, the anesthesiologist must attend to airway management, giving 100 percent oxygen and following vital signs with full monitoring (i.e., ECG, blood pressure, end-tidal concentrations of CO2, and pulse oximeter).

Coughing may be decreased by giving lidocaine (1.5 mg/kg IV) approximately 2 minutes before placement of the tracheostomy tube. Often, the sudden reestablishment of a good airway results in rapid correction of hypercarbia, resolution of stress, a decrease in endogenous catecholamines, and subsequent hypotension. Postobstructive pulmonary edema can also occur and has been reported in a young adult with coronary artery disease subsequent to relief of airway obstruction (intubated for epiglottitis). 188  A major early complication of tracheostomy, especially in children, is malpositioning of the tube. As soon as a tracheostomy tube is placed, end-tidal concentrations of CO2, breath sounds, and oxygen saturation must be checked. As soon as feasible, a chest radiograph should be obtained to verify correct tube placement and the absence of pneumothorax. Other early complications of tracheostomy include bleeding and local emphysema, which are usually exacerbated if the patient coughs and struggles.

The most important of the late complications of long-term tracheostomy is tracheal stenosis at the cuff site or stoma. 189  The use of high-volume low-pressure (15–20 mm Hg) cuffs inflated only when necessary and checked every 4 hours sometimes minimizes this complication. During general anesthesia, N2O diffuses into tracheal cuffs within 60 to 90 minutes, causing increased cuff pressure.

A Montgomery T-tube 190  or Olympic tracheal button must be carefully placed without tension. These devices have the advantages of having no cuff, producing less tracheal irritation and airway resistance, and allowing air to pass through the mouth for speech. On the other hand, they provide no protection from aspiration for the area above the device, and application of positive-pressure ventilation is difficult. In an emergency, the button is easily removed and replaced with a small endotracheal tube, which can then seal the airway and allow for use of positive-pressure ventilation, if necessary.

Postoperative care after tracheostomy requires administration of humidified oxygen, careful intermittent suctioning of secretions, attention to sterile precautions, and adjustment of cuff pressure to maintain 15 to 20 mm Hg. Prolonged tracheal suctioning not preceded or followed by oxygenation can result in arrhythmias secondary to hypoxia. Moreover, the tract from stoma to trachea is not fully established for 5 days. Therefore, changing the tube within 5 days of tracheostomy runs the risk of losing this tract. Under these circumstances, a pediatric laryngoscope may be helpful in holding the tissue apart and facilitating visualization of the trachea. For emergency airway management, a laryngoscope and small endotracheal tube should be at the bedside of all patients who have recently undergone tracheostomy.

Cricothyrotomy is another method of establishing an airway quickly (within 1–2 min) in an emergency, life-threatening situation. The complication rate of 8.6 percent is less than that for emergency tracheostomy. 191  The trachea is entered directly through an incision in the cricothyroid membrane at the third tracheal ring, just below the vocal cords. Disadvantages include damage to the cricoid cartilage that leads to tracheal collapse or stenosis, bleeding, and the need for insertion of a small tube. Emergency cricothyrotomy is a temporary procedure that secures an airway until a definitive tracheostomy can be established.

No patient should undergo injury or death because of upper airway obstruction. At the very least, the cricothyroid membrane can be punctured using a 12- to 14-gauge needle to provide temporary oxygenation until a proper airway can be established. This method of transtracheal ventilation through a large needle has been effective in preventing hypoxia and respiratory acidosis. 159, 192  Oxygen is provided by flushing oxygen at the rate of 15 L/min or by jet ventilation (40 psi) at a slow, intermittent rate of 6 breaths/min and an inspiratory, expiratory respiratory cycle of 14. This ratio allows time for passive expiration through a narrow channel. Otherwise, high airway pressure results, thereby decreasing venous return and arterial blood pressure and increasing the risk of pneumothorax.

Complications of Endotracheal Intubation

The perioperative complications of endotracheal intubation have been reviewed by many investigators 193, 194, 195, 196 (Chs. [39](file:///Volumes/Anesthesia/site/content/v03/030570r00.htm) and [72](file:///Volumes/Anesthesia/site/content/v05/050015r00.htm)). Fortunately, the more common complications are minor; however, some of the less frequent complications can be serious.

Injury during intubation is more likely in children, female patients, patients with poor dentition, and those undergoing difficult tracheal intubation. Blanc and Tremblay 194  listed more than 30 possible acute problems associated with intubation and extubation of the trachea, such as broken teeth, lacerations and perforations of the pharynx, subluxation of arytenoid cartilage, hoarseness, sore throat, paralysis of the vocal cords, and nerve damage. The overall incidence of laryngeal injury after short-term intubation is 6.2 percent, 197  the most common injury being hematoma of the vocal cord (4.5%). Mucosal lacerations occur in approximately 1 in 1,000 intubations.

Perforations of the trachea usually occur during difficult intubations using a stylet. If subcutaneous emphysema is noted after a difficult intubation, the patient must be evaluated for mediastinitis and pneumothorax.

Reflex responses to laryngoscopy and tracheal intubation are frequently minor, but they may be serious. Sympathetic responses are hypertension, tachycardia, and tachyarrhythmias. Vagal responses are laryngospasm, bradycardia, hypotension, cardiac arrest, and apnea. These responses are most likely during light levels of anesthesia and, in association with hypoxia, during periods of hypercarbia and acidosis. These reflexes may be diminished by pretreatment with lidocaine (intravenous or topical administration), narcotics, or b-adrenergic receptor blocking drugs and by ensuring an adequate depth of anesthesia at the time of laryngoscopy.

Pharyngitis and sore throat after tracheal intubation are not uncommon. Even patients undergoing only anesthesia by mask may complain of postoperative sore throat. This complication usually resolves within 72 hours. Causes include the use of dry gases, reaction to the lubricant, increased cuff size and pressure, patient motion (coughing, bucking) while the tube is in place, difficult intubation requiring repeated attempts, and excessive tube size. Hoarseness, indicating vocal cord injury, is another postintubation problem associated with tube size. Usually, mild postoperative hoarseness resolves within 5 to 7 days. Hoarseness that worsens or persists beyond 7 days requires evaluation by an otolaryngologist.

Vocal cord paralysis secondary to damage to the recurrent laryngeal nerve is a rare but more serious cause of hoarseness. This complication may occur because the endotracheal tube cuff presses the recurrent laryngeal nerve between the thyroid lamina and the arytenoid cartilage 193  or because of direct injury during head and neck surgery. Unilateral injury causes some change in voice and mild aspiration, but no respiratory obstruction. Bilateral recurrent nerve injury is more serious and may result in respiratory distress, stridor, and complete obstruction, as both true vocal cords become motionless and adducted. A tracheostomy may be required during the 6-week recovery period.

The use of the laryngeal mask airway does not necessarily avoid complications. Sore throats and even unilateral right hypoglossal nerve paralysis have been reported. 198  Inadvertent intubation of the esophagus or bronchi can be avoided by the following practices: observation of the tube as it passes through the vocal cords; checking the distance indicator at the teeth (21 cm for female patients and 23 cm for male patients); listening for equal bilateral breath sounds and for the absence of gastric sounds; checking for symmetric chest motion synchronous with squeezing of the ventilator bag; and noting the sustained presence of exhaled CO2 on a capnometer. CO2 may temporarily effuse from the stomach, having been forced there during the application of positive-pressure ventilation by mask. Adequate oxygenation, as evidenced by monitoring of the pulse oximeter, does not necessarily indicate proper endotracheal intubation. If the patient has breathed 100 percent oxygen for 4 to 5 minutes, oxygen desaturation following intubation of the esophagus may not occur for at least 2 to 3 minutes. Moreover, the presence of breath sounds does not always indicate a successful endotracheal intubation. A spontaneously breathing patient whose esophagus has been intubated can still produce valid breath sounds.

Cocaine

Cocaine is a naturally occurring alkaloid of the *Erythroxylon coca* plant. It is an ester of benzoic acid and the methylated base ecgonine. In addition to its local anesthetic effects on mucous membranes, cocaine is an excellent vasoconstrictive agent. For these reasons, it is used in intranasal surgery to provide anesthesia, to decrease bleeding, and to shrink congested mucous membranes. 199  Cocaine also has sympathomimetic effects, sensitizing organs to epinephrine and blocking the reuptake of released epinephrine at peripheral nerve terminals. 200  Therefore, cocaine should be avoided in hypertensive patients, especially those taking monoamine oxidase inhibitors.

In one study, intranasally applied cocaine (1.5 mg/kg) was absorbed rapidly, reaching peak levels in 30 to 45 minutes; these levels remained elevated for at least 120 minutes. 201  No important cardiovascular effects occurred during general anesthesia with halothane. Smaller intranasal doses (0.5–1 mg/kg) have been found to increase heart rate 10 beats/min and to raise both systolic and diastolic blood pressures approximately 10 mm Hg. 202  Higher doses (2 mg/kg) sensitize the myocardium to the arrhythmogenic effect of epinephrine, whereas even higher doses (5–10 mg/kg) depress the heart.

The response to cocaine varies. In some patients, even small doses of 0.4 mg/kg may cause ventricular fibrillation, cardiac arrest, hypertension, tachycardia, respiratory depression, or restlessness. The median lethal dose (LD50 ) for orally administered cocaine is approximately 500 mg. 203  For intranasal administration of a 4 percent solution, the safe recommended maximum dose is approximately 1.5 mg/kg. Each drop of a 4 percent solution contains about 3 mg of cocaine.

Cocaine is absorbed from the laryngeal tracheal mucosa as rapidly as if it were injected intravenously. It is metabolized primarily through ester hydrolysis by plasma pseudocholinesterase and is also slowly detoxified in the liver and excreted unchanged by the kidney. Patients with pseudocholinesterase deficiency may be sensitive to cocaine. The practice of adding epinephrine to cocaine is hazardous, and there is no evidence that this addition produces less bleeding at the site of surgery.

ANESTHESIA FOR EAR SURGERY

Local Anesthesia

Surgical otologic procedures such as premeatal operations, stapedectomy, and uncomplicated middle ear surgery of less than 2 hours‘ duration can be performed on selected patients using infiltration of local anesthetic and carefully titrated sedation. Patients should be able to understand, communicate, and be cooperative (i.e., remain still, especially during microscopic surgery of the middle ear). During the preoperative visit, the anesthesiologist should perform the same thorough medical evaluation as for general anesthesia. The goal of preoperative sedation is to render the patient calm, cooperative, and comfortable but not overmedicated (i.e., with obtunded reflexes) or out of touch with surroundings. Light sedation can be achieved by titrating intravenous propofol (0.5–0.7 mg/kg) during the injection of local anesthetic and, if necessary, by adding midazolam (0.02–0.04 mg/kg IV) during the procedure.

Nerve Block

Four nerves provide sensory innervation of the ear. The auriculotemporal nerve (the mandibular division of the trigeminal nerve) supplies the outer auditory meatus and can be blocked by injection of 2 mL of local anesthetic into the anterior wall of the external auditory meatus. The great auricular nerve (the cervical plexus nerve) supplies the medial-lower aspect of the auricle and part of the external auditory meatus. The auricular branch of the vagus runs between the mastoid process and the external auditory meatus to supply the concha and external auditory meatus. The great auricular and auricular (vagus) nerves can be blocked by injection of 2 to 3 mL of local anesthetic posterior to the ear canal (great auricular nerve). The tympanic nerve (the glossopharyngeal nerve) supplies the tympanic cavity and can be blocked topically by instillation of sterile 4 percent lidocaine. When a large perforation of the tympanic membrane has occurred, care must be taken not to place toxic substances into the auditory canal, lest they enter and damage the middle ear cavity.

Addition of epinephrine to the local anesthetic increases the intensity and duration of the effect and provides some local vasoconstriction, thereby decreasing bleeding. A safe dose of epinephrine is 0.1 mg (10 mL of 1:100,000 concentration) and may be repeated after 20 minutes, if necessary.

General Anesthesia

General anesthesia for ear surgery requires attention to preservation of the facial nerve, the effect of N2O in the middle ear, extremes of head positioning, the possibility of air emboli, blood loss, and, during microsurgery of the ear, control of bleeding, and prevention of nausea and vomiting.

Positioning of the Patient During Ear Surgery

When positioning the patient‘s head for surgery under general anesthesia, one must avoid extremes of neck extension or head torsion. Injuries can occur to the brachial plexus (stretch injuries) or cervical spine [(Ch. 26](file:///Volumes/Anesthesia/site/content/v03/030142r00.htm)). Patients with limited carotid artery blood flow are especially vulnerable to further decreases in blood flow from exaggerated neck positions.

Preservation of the Facial Nerve

Surgical identification and preservation of the facial nerve are essential during many ear operations. The goal is more easily accomplished and confirmed if the patient is not totally paralyzed. If a narcotic muscle relaxant technique must be used, the effects of the muscle relaxant should be monitored to ensure that at least 10 to 20 percent of muscle response remains. Otologic surgical procedures are associated with a 0.6 to 3.0 percent incidence of facial nerve paralysis. Intraoperative monitoring of evoked facial electromyographic activity may assist in functional preservation of the facial nerve during surgery in the mastoid/temporal bone area. 205

Nitrous Oxide and Middle Ear Pressure

The middle ear and paranasal sinuses are normal body air cavities that consist of open, nonventilated spaces [(Ch. 4](file:///Volumes/Anesthesia/site/content/v02/020059r00.htm)). The middle ear space is vented intermittently when the eustachian tube is opened. Expansion of these air spaces by replacing nitrogen with N2O reflects the 34-fold difference between the blood/gas coefficients of the two gases (0.013 for nitrogen versus 0.46 for N2O). Specifically, when inhaled in high concentrations, N2O enters the air cavities faster than nitrogen can leave. In a fixed cavity such as the middle ear, the result is an increase in pressure. 206  Normally, passive venting by the eustachian tube occurs at a pressure of approximately 200 to 300 mm H2 O. If eustachian tube function decreases because of surgical trauma, disease, or acute inflammation and edema, middle ear pressure can reach 375 mm H2 O within 30 minutes of the start of N2O.

In addition, after discontinuation of N2O, the gas is rapidly reabsorbed, and sustained, marked, negative middle ear pressure may develop. When eustachian tube function is abnormal, negative ear pressure of –285 mm H2 O can occur within 75 minutes of discontinuation of N2O. Such pressure may contribute to the development of serous otitis, disarticulation of the stapes, and impaired hearing. 196  Demonstrating these marked changes in middle ear pressure associated with N2O, Patterson and Bartlett 207  also noted hearing impairment caused by hematotympanum and disarticulation of stapes struts. These investigators believe that N2O anesthesia may be hazardous to hearing in patients who have had previous reconstructive middle ear surgery.

Transient worsening of middle ear function, rapid increases in middle ear pressures proportional to the inhaled concentration of N2O, nausea and vomiting, and rupture of the tympanic membrane have all been associated with elevated middle ear pressure and abnormal eustachian tube function during N2O anesthesia in susceptible patients. Susceptible patients include those with previous otologic surgery, acute or chronic otitis media, sinusitis, upper respiratory tract infection, enlarged adenoids, and pathologic conditions of the nasopharynx. Decreased compliance, increased resistance, and conductive hearing loss have also been observed in patients given N2O anesthesia for adenotonsillectomy.

A bulging eardrum and “lifting off” of the tympanic membrane graft can occur during tympanoplasty surgery. There is no evidence that using N2O (£50%) for general anesthesia for type 1 tympanoplasties will interfere with the graft placement or outcome of the surgical procedure. 208  To avoid complications, however, the anesthetist should limit the concentration of N2O to 50 percent and should discontinue administration 15 minutes before closure of the middle ear. The subsequent decrease in subatmospheric pressure can be avoided by flushing the middle ear cavity with air prior to closure of the tympanic membrane.

Microsurgery of the Ear

During microsurgery of the ear, the technique selected for anesthesia should help to provide good operative conditions for the surgeon. A 10- to 15-degree head-up tilt increases venous drainage, keeps venous pressure low, and decreases venous bleeding. The use of a volatile anesthetic agent helps to control arterial blood pressure. Microsurgery of the ear may require additional local vasoconstriction to control bleeding. Local infiltration of 0.1 mg of epinephrine (10 mL of a 1:100,000 concentration), repeated within 20 minutes, is a safe practice in a well-ventilated patient given halothane anesthesia. Isoflurane does not sensitize the myocardium to catecholamines to the same extent as does halothane. Topical application of epinephrine in the ear usually requires only a few drops. Concentrations higher than 150,000 do not provide any additional vasoconstrictive effects.

The need for deliberately induced hypotension during microsurgery of the ear is questionable 81, 209 [(Ch. 41](file:///Volumes/Anesthesia/site/content/v03/030620r00.htm)). The goal should be diminished bleeding, rather than an absolutely bloodless field. Inducing hypotension for ear, nose, or throat procedures, Condon 81  concluded that, even when precautions were taken, controlled hypotension was not free of complications. These complications, however uncommon, are usually major problems involving the heart or CNS. Furthermore, in a blind study on the use of controlled hypotension for ear surgery, Eltringham et al 210  found no correlations between blood pressure and quality (i.e., dryness) of the operative field. Modified hypotensive techniques based on controlled ventilation with halothane have been reported to provide successful general anesthesia for ear surgery. Multidrug combinations of nitroglycerin, hydralazine, propranolol, droperidol, and others can lead to excessive hypotension in which rapid reversal is not possible. In this author‘s experience, satisfactory conditions for microsurgery of the ear can be provided by placing the patient in a 15-degree head-up position, maintaining systolic blood pressure at approximately 85 mm Hg, using controlled ventilation with a volatile agent, and adding narcotic and local infiltration of topical application of epinephrine, if necessary.

In summary, general anesthesia using a volatile agent is the first choice for microsurgery of the ear. No muscle relaxation is required. Moreover, if the administration of N2O must be discontinued, the effects of the potent anesthetic agent remain, identification of the facial nerve is not impeded, and relative hypotension (systolic blood pressure 80–85 mm Hg) can easily be maintained.

Middle Ear Surgery: Nausea and Vomiting

Procedures on the middle ear are likely to cause postoperative emesis [(Ch. 65](file:///Volumes/Anesthesia/site/content/v04/040507r00.htm)). PONV can undo the results of the delicate middle ear reconstruction. The anesthetic management of middle ear surgery should include a plan to minimize PONV. Many regimens have been shown effective, including propofol infusion, 211  granisetron, 212  transdermal scopolamine, 213  ondansetron, 214  droperidol, and eliminating N2O. 138, 215  Splinter et al 216  were unable to demonstrate that N2O induces vomiting in children after the brief general anesthetic for myringotomy. PONV may be controlled with intravenous doses of a potent antiemetic drug (e.g., droperidol, 0.01/kg; ondansetron, 0.05 mg/kg; or dolasetron, 0.20 mg/kg) given during surgery.

Myringotomy

Bilateral myringotomy with tube placement is the second most frequently performed pediatric surgical procedure. 216, 217  Some form of analgesia is required in most children after this brief outpatient procedure. 218  Derkay et al 217  found that when intraoperative ear drops mixed with 4 percent lidocaine were used, the preoperative oral analgesics were of little added benefit. Preoperative oral acetaminophen, 219  or acetaminophen with codeine, 218  and even intranasal butorphanol 220  have been recommended as effective.