Chapter 29

Anesthesia for Pediatric ENT Surgery

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Ear Surgeries
- Myringotomy and Tube Placement
- Tympanomastoidectomy
- Tympanoplasty

Nasal Surgery
- Nasal Cautery
- Nasal Fracture Reduction
- Juvenile Angiofibroma Resection

Upper Airway Surgery
- Tonsillectomy
- Peritonsillar Abscess Incision and Drainage
- Bleeding Tonsil
- Adenoidectomy
- Esophageal Foreign Body
- Frenulectomy
- Dental and Oral Surgical Procedures

Laryngeal Surgery
- Laryngoscopy and Bronchoscopy
- Suspension Laryngoscopy
- Tracheostomy

Lower Airway Surgery
- Bronchial Foreign Body

Neck Surgery
- Thyroglossal Duct Cyst
- Branchial Cleft Cyst
- Neck Mass Biopsy and Excision
- Cystic Hygroma

ENT emergencies that manifest as life-threatening airway obstruction are extensively reviewed in Chapter 18.

Ear, nose, and throat (ENT) surgery represents a large proportion of pediatric surgeries and remains one of the most challenging because of the frequency of airway obstruction in infants and small children. The anesthesiologist must be familiar with a variety of airway management techniques that are unique for each type of procedure, as well as the different types of airway instruments used by otolaryngologists.

This chapter reviews the anesthetic implications for the most common ENT procedures performed in children.

Myringotomy and Tube Placement
Otitis media is a bacterial infection that develops within a transudate in the middle ear in susceptible children. It is usually caused by chronic eustachian tube obstruction from either congenital narrowing or adenoidal hypertrophy. Myringotomy and tube placement consists of the insertion of tiny ventilating tubes through the tympanic membrane to drain fluid from the middle ear and prevent future fluid collections. It is the most common surgical procedure requiring general anesthesia in children, who frequently present with fever and upper respiratory tract infections that will not abate until the ear fluid is drained. The major focus of the preoperative assessment is to ensure that the child does not have any lower airway symptoms that indicate acute reactive airway disease or pneumonia.

The standard anesthesia technique for myringotomy and tube placement consists of an inhalational induction, usually with sevoflurane and N₂O, although halothane is still used in many centers. Once the child has reached a depth of unconsciousness sufficient to prevent response to a painful stimulus, the anesthesiologist turns the child’s head to the side while maintaining mask anesthesia, and the tubes are placed by the surgeon using a microscope (Fig. 29-1). Intravenous access is usually not necessary. Each ear tube insertion typically lasts no more than 5 minutes. Many children will manifest upper airway obstruction when the head is turned. This usually abates with application of continuous positive airway pressure (CPAP) or placement of an oral airway. Laryngospasm may occur if the depth of anesthesia is insufficient for the procedure. Central or obstructive
apnea may occur and is treated with positive-pressure ventilation.

Postoperative pain is severe in some children immediately after the procedure and can occasionally last a few hours. Thus prophylactic analgesia is indicated. Choices include oral or rectal acetaminophen 40 mg/kg, ibuprofen 10 mg/kg, codeine 0.5–1 mg/kg, or oxycodone 0.1 mg/kg. Intranasal or intramuscular fentanyl 1–2 µg/kg, administered while the child is anesthetized, provides adequate postoperative analgesia and decreases agitation during emergence from general anesthesia without prolonging discharge times. Similar results are attained using intranasal butorphanol 25 µg/kg. Postoperatively, children with preexisting upper respiratory tract infections may develop hypoxemia and require oxygen therapy.

**Tympanomastoidectomy**

Indications for a tympanomastoidectomy include chronic otitis media or presence of a cholesteatoma. The surgery is performed through an incision behind the ear to expose the ear canal and tympanic membrane, or through the ear canal. The ear canal is widened and a portion of the mastoid bone is removed. The eardrum is rebuilt and the cholesteatoma is removed if present. These children are usually otherwise healthy, but may have hearing loss. The procedure is performed in the supine position with the child’s head turned away from the side of the surgery. The OR table is turned 90–180 degrees away from the anesthesia machine. Therefore, the anesthesiologist must anticipate the requirement of a breathing circuit with sufficient length. During the procedure, the head and neck are completely covered with drapes, so access to the airway is difficult. There is minimal blood loss or third-space fluid losses. If the surgeon requests facial nerve monitoring, and paralysis is desired for endotracheal intubation, an intermediate-acting neuromuscular blocker should be chosen and used for intubation only. The use of N₂O should be discussed with the surgeon who may request that it be discontinued prior to placement of a tympanic graft. A temporary urinary catheter should be considered for procedures greater than 4 hours duration. Hyperthermia is possible if a warming blanket is used. The main postoperative concern is nausea and vomiting, so antiemetic prophylaxis should be administered. Postoperatively, children may be discharged home if they are well hydrated and do not have severe pain.

**Tympanoplasty**

A tympanoplasty is repair of a perforated ear drum using a temporalis fascia graft. It may also involve reconstruction of the bones of the middle ear. A postauricular approach is most often used. Virtually all anesthetic implications and techniques are the same as those for tympanomastoidectomy.

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### NASAL SURGERY

**Nasal Cautery**

Nasal cautery is performed in children who have chronic nose bleeds secondary to friable blood vessels along the anterior portion of the nasal septum. The children are usually healthy. The procedure consists of brief electrocauterization and typically lasts no more than 10–15 minutes. Some anaesthesiologists may choose to provide mask anesthesia while intermittently removing the mask for the surgeon to cauterize the vessels. Laryngeal mask airway (LMA) or endotracheal tube placement are reasonable options, especially if the child is expected to bleed into the back of the pharynx. Postoperative analgesia is minimal and easily treated without opioids.

**Nasal Fracture Reduction**

Nasal fractures occur commonly in children following facial trauma. Reduction and fixation is rarely a surgical emergency. The children are scheduled for elective closed or open reduction as an outpatient. Closed reduction consists of the manipulation of the nasal bones externally with the assistance of instruments through the nasal openings. Bleeding is typical, though not enough to be clinically important. However, there is a significant amount of blood that enters the nasopharynx. For this reason, most pediatric anaesthesiologists will choose LMA placement or endotracheal intubation for airway management, and will thoroughly suction the pharynx prior to removal. Postoperative pain may require opioid analgesia. Since postoperative nausea and vomiting is common, a prophylactic antiemetic is indicated.

**Juvenile Angiofibroma Resection**

A juvenile angiofibroma is a benign vascular tumor of the posterior nasopharynx that can spread into contiguous structures. Adolescent boys are most often affected and present with chronic nasal obstruction or painless nasal bleeding that is not associated with trauma. Many patients will undergo preoperative embolization to limit intraoperative bleeding, which may be severe. Additional preoperative assessment includes a complete blood count, coagulation studies, and a type-and-crossmatch. Induction and maintenance of anesthesia are routine. Once consciousness is lost, two large-bore intravenous catheters are inserted for volume replacement and possible blood transfusion. An arterial line is often placed, depending on the size of the tumor and extent of the procedure. Airway management consists of a straight or
RAE oral endotracheal tube, depending on the surgical approach. A temporary urinary catheter should be placed if the anticipated duration of the surgery is more than 3–4 hours. The surgical approach is dependent on the size and exact location and spread of the tumor. The main intraoperative concern is blood loss. At the end of the procedure the nasal cavity is frequently packed. Depending on the extent of the surgical resection these children may remain intubated at the end of the procedure and mechanically ventilated in the ICU until their vital signs and fluid status have stabilized.

**UPPER AIRWAY SURGERY**

**Tonsillectomy**

Tonsillectomy remains a common childhood surgical procedure. There are two indications: recurrent infection (usually in children older than 4 years) and sleep apnea (usually in children under 4 years). When performed for children with sleep apnea, adenoidectomy is usually performed at the same time. Anesthetic implications of children with sleep apnea are discussed in Chapter 4.

Most routine tonsillectomies are performed as outpatient surgery. Certain groups of children with a high risk of postoperative upper airway obstruction should be scheduled for overnight hospital admission. This includes children less than 4 years of age and those with severe sleep apnea. In addition, children with coexisting medical problems (e.g., trisomy 21, obesity, bleeding disorders) should be hospitalized postoperatively.

Some surgeons require preoperative hemoglobin testing and coagulation studies, even though there is little support in the literature for this practice, unless there is a history of a bleeding disorder in the child or the family. Nonsteroidal anti-inflammatory drugs (NSAIDs) should be discontinued at least days prior to surgery. A preoperative oral anxiolytic should be administered at a decreased dose in young children with significant airway obstruction. Oral acetaminophen 15 mg/kg may be added to the premedication to help decrease postoperative pain.

The goals of anesthetic management for tonsillectomy are a motionless patient during the procedure, a rapid and smooth emergence, postoperative pain relief, and control of postoperative nausea and vomiting. Following induction of anesthesia, an oral RAE endotracheal tube is inserted to accommodate the mouth opening device used by the surgeon. There are several types of these devices; each is designed to secure the endotracheal tube against the tongue in the midline, and allow maximal surgical exposure of the pharynx. A growing number of pediatric anesthesiologists routinely use an LMA for airway management during tonsillectomy. Advantages and disadvantages of LMA use during tonsillectomy are listed in Box 29-1. Adjuvant medications include an opioid for pain and a 5-HT 3 antagonist to help prevent postoperative nausea and vomiting. Dexamethasone also decreases the incidence of postoperative nausea and vomiting, is associated with improved postoperative fluid intake, and lessens the severity of postoperative pain. Neuromuscular blockers are administered by some anesthesiologists. Maintenance of anesthesia can consist of a combination of an inhalational agent, N 2 O, or continuous infusion of propofol. Propofol maintenance is associated with less postoperative nausea and vomiting.

Once the anesthesiologist has taped the endotracheal tube or LMA appropriately, the OR table is turned through 90 degrees. A rolled-up sheet or similar “shoulder roll” is placed underneath the shoulders of the patient, and the head is placed in extension. When the surgeon inserts the mouth gag, the child’s mouth is maximally opened (Fig. 29-2). During this process the endotracheal tube may be pulled out of the trachea or critically compressed. Therefore, the anesthesiologist should ensure that ventilatory parameters remain the same as before the gag was placed. In addition, because of the surgeon’s viewpoint from above the head of the child, he or she may not notice that certain portions of the lips and tongue have become pinched by the gag. The anesthesiologist must carefully observe this process to ensure that injury does not occur.

During tonsillectomy, there are several anesthetic concerns. Blood loss varies and may be significant, but is difficult to measure. However, it is rarely severe enough to warrant transfusion. Fluids should consist of an isotonic solution to replace the preoperative deficit, blood loss, and minimal insensible losses. Some surgeons prefer to infiltrate the tonsillar fossae with a local anesthetic to decrease postoperative pain. Others, however, feel that this practice results in a higher incidence of postoperative bleeding. At the end of the procedure, the surgeon may pass a soft catheter to suction gastric contents. However, blood is rarely recovered, and there is no evidence that this practice influences the incidence of postoperative nausea and vomiting. Once the surgeon has completed the procedure the table is turned back to the anesthesiologist and an oral airway or bite block is inserted into the mouth to prevent the child from biting down and compressing the endotracheal tube during emergence. The nasal passages are gently suctioned for secretions and excess blood but the catheter should go no farther than the anterior nasal cavity to avoid dislodging a fresh clot from the adenoid bed in the nasopharynx. Similarly, oral suctioning should be gentle and limited to the anterior midline of the oral cavity so that the tonsillar fossae are avoided. Bright red blood that is continually suctioned during emergence should prompt a reexploration before the child is awakened.

There are two schools of thought with regard to the safest and most appropriate method for emergence and
tracheal extubation following tonsillectomy: wide-awake versus deep extubation. The major advantage of a wide-awake extubation is the patient’s conscious ability to maintain airway patency immediately following the procedure. The main purported disadvantage is an increased tendency for bleeding secondary to coughing and bucking during emergence, which may disrupt clots at the surgical site. The main advantage of a deep extubation is the avoidance of bleeding during emergence, and the facilitation of throughput in a busy surgical suite. Disadvantages include possible respiratory depression and failure to maintain airway patency, and laryngospasm during the semiconscious phase of emergence as a result of secretions or blood in the larynx.

Following an awake tracheal extubation, the child is carefully observed for several minutes to ensure airway patency and the ability to maintain spontaneous ventilation without hypoxemia. The child should be kept in the operating room until he or she demonstrates the ability to maintain a patent airway without jaw thrust or chin lift. Occasionally, an oral airway may be left in place during transportation to the intensive care unit. The classic “tonsil position” with the child lying on one side and with the head lower than the body will facilitate upper airway patency and draining of blood and secretions from the mouth. This may be the case for the relatively unconscious child. In practice, however, this is rarely utilized since the supine position is preferred for airway management during transport.

At The Children’s Hospital of Philadelphia, a wide-awake extubation technique is preferred. Coughing during emergence is minimized by administering a moderate dose of intraoperative morphine (0.075–0.15 mg/kg) and low concentrations of inhalational agent. Neuromuscular blockade is usually administered. Box 29-2 describes our standard anesthetic protocol. Using this technique, bleeding during emergence and postoperative laryngospasm are exceedingly rare.

Other centers, however, are equally adamant about efficacy and safety of the deep extubation technique. This technique requires a relatively greater use of inhalational agent and less opioid, to facilitate adequate airway patency following tracheal extubation. Local anesthetic infiltration is also recommended. If deep extubation is routinely used, the institution must develop a culture within the postoperative recovery site that facilitates expedient treatment of transient airway obstruction and laryngospasm.

The most important postoperative concern following tonsillectomy is upper airway obstruction. The precise cause is unknown and may be related to airway edema, residual effects of general anesthesia, or a combination of the two. It occurs more often in children less than 3 years of age, and in children with preexisting sleep apnea. It most often manifests within the first postoperative 30 minutes. Delayed upper airway obstruction is uncommon. Initial treatment consists of optimal positioning of the head and neck in a position that is most consistent with airway patency, cool mist in oxygen, and administration of steroids if not already given. If these measures fail to relieve continuing hypoxemia (SpO2 < 90%), placement of a soft lubricated nasopharyngeal airway is indicated. Most children with distress secondary to upper airway obstruction will allow placement of this device without much of a struggle. Should this measure be necessary, the child should be admitted to a postoperative hospital unit with close nursing supervision (e.g., PICU). Should the child remain hypoxic despite placement of a nasopharyngeal airway, tracheal intubation is then indicated, with a trial of extubation at a later time.

The most common postoperative concerns following tonsillectomy are pain relief and postoperative nausea and vomiting. Opioids should be titrated to achieve sufficient analgesia while avoiding respiratory depression and upper airway obstruction. Many children will alternate between crying in pain and falling asleep and becoming hypoxic. This is a continual challenge for the anesthesiologist and intensive care staff. Outpatients with moderate pain may be given oxycodone or equivalent analgesic syrup prior to leaving the facility. NSAIDS are not administered to tonsillectomy patients for 2 weeks because of the increased incidence of postoperative bleeding.

Nausea and vomiting occur in up to 75% of children following tonsillectomy. They are likely caused by residual swallowed blood that irritates the lining of the stomach, or other unknown factors related to the site of the surgery or the anesthetic technique (e.g., opioids). Vomiting can result in exacerbation of bleeding from the tonsillectomy site, and dehydration. Treatment includes maintenance of intravenous fluid therapy, antiemetics, and continuous observation for hypovolemia and anemia. Continued presence of blood in the vomitus should initiate examination for a primary bleed. Additional doses of a 5-HT3 antagonist may be administered, but are generally less effective for treating nausea alone. Droperidol is often effective, especially for nausea. However, at the time of this writing it is no longer used by most centers because of the “black box warning” concerning its association with a prolonged QT interval. Metoclopramide is usually ineffective in this setting. Most centers will employ one of a number of other antiemetics for refractory vomiting. Children with ongoing postoperative nausea and vomiting should have their intravenous access maintained to provide continuous hydration. If vomiting is continuous and severe, hospital admission is warranted for continuation of intravenous hydration and antiemetic therapy. The vast majority of children will no longer manifest postoperative nausea and vomiting by the second postoperative day.
Additional postoperative complaints following tonsillectomy include otalgia, fever, uvular swelling, and velopharyngeal insufficiency.

**Peritonsillar Abscess Incision and Drainage**

A peritonsillar abscess results when bacterial tonsillitis spreads to the tonsillar fossae and soft palate. It produces fever, severe sore throat, dysphagia, and trismus from pterygoid muscle spasm. Patients may be dehydrated from the fever and the inability to drink. Preoperative considerations include administration of antibiotics, intravenous isotonic fluids, and a MRI or CT scan of the neck to estimate the spread of the infection and severity of airway obstruction. Airway evaluation is often difficult due to the presence of trismus. Preoperative sedatives are avoided if airway obstruction is evident.

Induction of anesthesia will depend on the likelihood of a difficult intubation. If the anesthesiologist suspects a potential difficult ventilation or intubation, spontaneous ventilation should be maintained during induction of anesthesia until it is known that positive-pressure ventilation is successful. If a difficult airway is not suspected, a rapid sequence induction and tracheal intubation are indicated. The trismus will abate upon administration of general anesthesia. The anesthesiologist must be prepared for rupture of the abscess during direct laryngoscopy, and be prepared with a double-suction set-up, various sized styletted, cuffed, oral RAE endotracheal tubes, and an extra working laryngoscope. Visualization of the glottic opening may be difficult secondary to altered pharyngeal anatomy. The intraoperative anesthetic implications are the same as for a tonsillectomy. Tracheal extubation should take place when the child is fully awake because of the possibility of residual blood in the stomach. Postoperative concerns are the same as for residual pharyngeal swelling.

**Bleeding Tonsil**

Bleeding following tonsillectomy can be severe and life-threatening. Primary bleeding occurs in the first 24 hours and is a direct result of residual operative bleeding. Secondary bleeding occurs 5–10 days postoperatively as a result of scab dislodgement. These cases are usually considered surgical emergencies. It is difficult to estimate the blood actually lost. Most is swallowed, and some children will vomit this swallowed blood but estimates of its volume are inaccurate. Therefore, anesthesiologists should assume hypovolemia and anemia until proven otherwise. The preoperative history should focus on the duration of the vomiting, and presence of any indicators of hypovolemia or anemia, such as dizziness or fainting. Physical exam should focus on detection of hypovolemia or anemia by checking skin turgor, signs of dehydration, and presence of pallor. Preoperatively, IV access is obtained, and blood samples are sent for a CBC and coagulation studies. An additional blood sample should be retained for possible type-and-cross if the hemoglobin level is low. Aggressive fluid hydration with an isotonic solution is geared toward normalization of vital signs and adequate urine output. Children often remain normotensive despite hypovolemia and anemia. Unless the bleeding is active and brisk, normalization of fluid status is the goal prior to surgery. The anesthesiologist should review an available anesthetic record from the original surgery to determine the presence of problems or issues that would influence the subsequent anesthetic technique (e.g., difficult ventilation or intubation). Small doses of intravenous midazolam may be administered shortly before surgery under the direct supervision of the anesthesiologist. Some anesthesiologists may wish to administer intravenous metoclopramide (0.1 mg/kg) to facilitate gastric emptying. The OR should be prepared with a double-suction set-up, several different sized styletted, cuffed, oral RAE endotracheal tubes, and an extra working laryngoscope.

Rapid sequence induction of anesthesia and tracheal intubation is indicated using sodium pentothal or propofol, and succinylcholine or rocuronium. If hypovolemia is suspected, lesser doses of these hypnotic agents should be used to avoid hypotension upon induction of general anesthesia. Alternatively they can be combined with ketamine, or ketamine can be used alone. Occasionally the anesthesiologist will encounter a situation whereby the pharynx is filled with blood, thereby impeding adequate visualization of the laryngeal inlet. Simultaneous hypotension secondary to systemic vasodilation in a child with preexisting hypovolemia may occur. These are tense moments – the ENT surgeon should be present in the OR during induction, and the most qualified anesthesiologist available should be managing the airway. Once the airway is secured by tracheal intubation, the stomach can be suctioned. Intraoperative anesthetic considerations are the same as for a routine tonsil with the exception of more vigilant attention to blood loss and fluid replacement. Tracheal extubation should occur with the child fully awake because of the possibility of residual blood in the stomach. Postoperative concerns are the same as after routine tonsillectomy and include pain and emesis.

**Adenoidectomy**

Adenoidectomy is primarily indicated in young children with chronic nasal obstruction, chronic sinusitis, and middle ear infections caused by eustachian tube blockage. Upper respiratory illnesses are extremely common, and often do not abate until after the surgery has been performed. Perioperative anesthetic considerations are essentially the same as for tonsillectomy, except for a
This procedure with general anesthesia because of a lesser amount of postoperative pain, and less chance for postoperative upper airway obstruction. Morphine is often limited to 0.05 mg/kg intraoperatively, and then titrated to achieve analgesia in the intensive care unit.

**Esophageal Foreign body**

In the course of placing objects in their mouths, toddlers will occasionally swallow these objects, which may become stuck in the esophagus. Most commonly, a coin becomes lodged in the proximal esophagus and must then be removed under general anesthesia with endotracheal intubation. Severe pain or airway obstruction are the only reasons this procedure becomes an emergency. Otherwise, the child should be admitted, made nil-by-mouth (NPO), and intravenous access obtained with administration of maintenance fluids. A radiograph should be obtained just prior to surgery to confirm that the coin has not already passed into the stomach. In the preoperative holding area, intravenous midazolam may be titrated to effect. Induction and maintenance of anesthesia is routine, with the expectation that this procedure will last no more than 5–10 minutes. If the anesthesiologist suspects a residual full stomach, then rapid sequence induction and tracheal intubation are indicated. Cricoid pressure may or may not be applied, depending on the location of the foreign body. The OR table is turned 90 degrees away from the anesthesiologist and the surgeon uses a rigid esophagoscope to remove the coin. Postoperative pain is usually mild and does not ordinarily require opioids.

**Frenulectomy**

A frenulectomy is an elective procedure that entails cutting the frenulum, which is the midline structure below the tongue. It is indicated for ankyloglossia, a condition of restricted tongue movement due to congenital overgrowth of the frenulum. It may be performed by a dissection technique and sutures, or using electrocautery, or both. Children are usually healthy. Airway management varies depending on the preference of the surgeon and anesthesiologist. Spontaneous ventilation via mask anesthesia or nasopharyngeal airway is easily accomplished if the surgeon is amenable. Others will feel more comfortable with placement of an LMA or endotracheal tube, because of the possibility of bleeding into the back of the pharynx. Postoperative pain is mild to moderate and responds to small doses of opioids and/or ketorolac.

**Dental and Oral Surgical Procedures**

The most common dental procedures requiring general anesthesia in children consist of extractions and restorations of teeth. Children are often scheduled for this procedure with general anesthesia because of a previous failure to cooperate using sedative techniques. Another reason to use general anesthesia is when mild sedation is untenable because of the presence of developmental delay or other behavioral problem. Many children have preexisting comorbidities. These should be completely investigated prior to the day of the procedure. Premedication with an anxiolytic is usually indicated. Uncooperative adolescents with developmental delay may refuse oral premedication and require intramuscular administration of ketamine (see Chapter 12).

An inhalational induction of general anesthesia is usually performed. Neuromuscular blockade is optional. After the child loses consciousness, a head wrap is snugly applied to the head to use as a secure attachment for the endotracheal tube (Fig. 29-3). A nasotracheal intubation is performed using a nasal RAE tube, aided by a Magill forceps. The OR table may be turned 90 degrees away from the anesthesiologist. All connections of the breathing circuit must be checked and appropriately tightened prior to beginning the procedure. Fluid requirements are minimal. Hyperthermia is possible during long procedures. Unintentional breathing circuit disconnections or obstructions of the capnograph line are possible hazards. The dentist or oral surgeon will usually infiltrate a moderate amount of local anesthesia. Administration of acetaminophen and/or ketorolac may help alleviate postoperative residual soreness. Small doses of an opioid may also be required.

**LARYNGEAL SURGERY**

**Laryngoscopy and Bronchoscopy**

Direct laryngoscopy and flexible or rigid bronchoscopy are used as part of a diagnostic work-up in the evaluation of respiratory compromise (e.g., laryngomalacia, subglottic stenosis), as a therapeutic tool for the treatment of laryngeal lesions (e.g., papilloma, cysts), and for the removal of foreign bodies from the upper or lower airways.

A variety of medical conditions may cause airway abnormalities that require diagnostic or therapeutic intervention. As an example, children born prematurely are especially prone to develop subglottic stenosis, and are frequently evaluated for chronic stridor, or inability to be successfully weaned from mechanical ventilation. The one common theme among children presenting for laryngoscopy and bronchoscopy is an obstructed upper or lower airway that may worsen with the loss of pharyngeal muscle tone that accompanies infection of general anesthesia, or present difficulty with endotracheal intubation.

The preoperative history should consist of a thorough review of previous anesthetics and optimization of comorbid conditions. Physical exam is focused on upper airway anatomy and the severity of existing airway obstruction. In the case of potentially significant airway obstruction,
the history and physical exam will determine the anesthetic approach to securing the airway (see Chapter 18). There are no specific requirements for preoperative laboratory testing. Radiographic studies of the head and neck region should be reviewed to assess the potential for airway obstruction during induction of general anesthesia.

Preoperative anxiolysis is tailored to the age and medical condition of the patient. Sedative medications may exacerbate existing airway obstruction and lead to life-threatening hypoxemia. Intravenous atropine or glycopyrrolate is frequently administered to dry airway secretions, to prevent vagal-induced bradycardia, and to attenuate cholinergic-mediated bronchoconstriction during airway manipulation. All appropriate equipment and personnel for dealing with a potentially difficult airway, including surgical equipment for tracheostomy, should be available. Preoperative communication with the surgeon will facilitate a precise understanding of the procedural components and will enable the anesthesiologist to develop a plan for airway management and the subsequent anesthetic technique.

Flexible bronchoscopy allows for dynamic assessment of the upper airway during spontaneous respiration, as well as for an evaluation of the peripheral tracheobronchial tree. It is particularly helpful for the evaluation of laryngomalacia, tracheomalacia, and bronchomalacia. Flexible bronchoscopy is performed soon after the patient loses consciousness so that spontaneous respiration is maintained. It is commonly performed through a device attached to the anesthesia mask to allow concomitant inhalation of oxygen and inhalational anesthetic during the procedure.

A rigid bronchoscope is a stainless steel hollow tube that is used for diagnostic and therapeutic procedures within the airway below the glottis. The distal end is blunt, and the proximal end contains a ventilation side-port that attaches to the standard anesthesia breathing circuit. A thinner telescope with an optical eyepiece is placed coaxially within the rigid bronchoscope and allows for magnified and illuminated visualization of the airway (primarily below the glottis) while retaining the ability to provide adequate ventilation (Fig. 29-4). When the telescope is removed, instruments can be passed through the bronchoscope to retrieve foreign bodies, resect masses, etc., while maintaining oxygenation and ventilation. The rigid bronchoscope is particularly suited for difficult airway management because of its ability to bypass laryngeal and tracheal lesions that compress the airway and contribute to difficult ventilation or intubation. It may be life-saving in the case of a mediastinal mass that is compressing the bronchial tree below the carina (see Chapter 8).

There are a variety of sizes and lengths of pediatric bronchoscopes that are chosen on the basis of the age and size of the child (Table 29-1). The bronchoscope size is chosen to give the surgeon the best possible view while causing the least amount of trauma to the glottis and subglottic tissues. The time taken to perform bronchoscopy should be as short as possible to decrease the risk of obstructive edema secondary to vocal cord and subglottic trauma. In some cases, the surgeon may choose to examine the glottis and the subglottis with the telescope alone to minimize trauma to this region. In this case, simultaneous ventilation is not possible; preoxygenation will increase the duration of apnea before hypoxia intervenes.

Various successful methods have been reported for anesthetizing children for bronchoscopy. Anesthetic induction can be accomplished using inhaled sevoflurane or an intravenous hypnotic agent. Following loss of consciousness, and prior to airway manipulation, intravenous and topical lidocaine can be administered to prevent the occurrence of protective airway reflexes such as gag and laryngospasm. Topical lidocaine within the lower airway may precipitate reflex bronchoconstriction unless preceded by intravenous lidocaine. Small doses of an opioid can be carefully titrated to maintain spontaneous ventilation, which is maintained during flexible bronchoscopy to evaluate dynamic function of the airway. Spontaneous ventilation should always be maintained with a potentially difficult ventilation or intubation. Neuromuscular blockers are administered only after adequate positive-pressure ventilation has proved successful. Flexible bronchoscopy is initially performed with the head of the OR table facing the anesthesiologist, so that mask ventilation can be optimally continued throughout the procedure.

The anesthetic plan for rigid bronchoscopy will be largely determined by the a priori choice of spontaneous or positive pressure ventilation during the bronchoscopy. This choice is influenced by the personal preferences of the anesthesiologist and surgeon, who must agree on an acceptable technique prior to administration of anesthesia. There are times, however, when this decision will be made during the case, depending on the surgeon’s findings and the patient’s clinical condition. With either ventilatory method, these procedures entail a large percentage of time that the child’s airway is open (i.e., exposed to the atmosphere when the surgeon removes the optical eyepiece or removes the bronchoscope). For this reason, a total intravenous anesthesia (TIVA) technique is preferred to decrease OR pollution from inhalational agents and provide an uninterrupted source of general anesthesia to the patient.

There are advantages and disadvantages of both spontaneous and controlled ventilation methods during rigid bronchoscopy. If spontaneous ventilation is maintained, continuous ventilation is occurring, despite interruptions in the anesthesia breathing circuit. For some obstructive lesions, negative-pressure breathing may provide better
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tinary stability. Thus, topical anesthesia to the airways is an

A controlled ventilation technique, which usually consists of administration of a neuromuscular blocker, relies on intermittent positive-pressure breaths between apneic periods when the surgeon instruments the airway, or uses the laser. Its advantages include the ability to provide optimal oxygenation and ventilation during the breathing phase, and assurance of lack of patient movement to airway manipulation. Its obvious disadvantage is that during periods of apnea, even with preoxygenation, there is a limited time before oxymemoglobin desaturation will occur, and the child will require additional positive-pressure breaths. Another significant disadvantage is the lack of assurance that positive-pressure ventilation will be successful with an obstructive lesion within the airway. In the case of a foreign body lodged within the bronchial tree, a theoretical disadvantage of positive pressure is the unintentional movement of the object further distally. This can worsen airway exchange or create a ball-valve effect with hemodynamic consequences secondary to lung compression of vascular structures. Fortunately, this complication is extremely rare.

Once the child is adequately anesthetized, and just prior to performing rigid bronchoscopy, the OR table is turned 90 degrees away from the anesthesiologist, while mask ventilation is continued by the anesthesiologist from a side position (Fig. 29-5) or by an assistant at the head of the table until the surgeon is optimally prepared to instrument the airway. The goal of the entire process should be a smooth, coordinated, sharing of the child’s airway with a combination of optimal oxygenation, ventilation, and surgical exposure.

Suspension Laryngoscopy

Suspension laryngoscopy is used mainly for procedures of the upper airway with the carbon dioxide laser. The child’s head is fixed in a constant position that provides an optimal view of the larynx (Fig. 29-6). An endotracheal tube can be held in place by the suspension laryngoscope. If the endotracheal tube remains in place during the laser treatment, it must be wrapped with aluminum tape to decrease the chances of an airway fire. Alternatively, several commercial laser-safe endotracheal tubes are available. Removing the endotracheal tube during the laser treatments will optimize visualization for the surgeon and remove a possible source of an airway fire. Oxygenation and ventilation is then provided by one of two methods: either intermittent endotracheal tube placement between apneic laser treatments, or insufflation of oxygen using a jet ventilator device that is inserted into the side port of the suspension laryngoscope proximal to the glottis. The jet ventilator device is attached to a standard 50 psi wall outlet and a valve is used to decrease the driving pressure required for adequate chest excursion (usually 10–15 psi) and to avoid barotrauma. The valve is manually opened 15–20 times per minute to provide alveolar ventilation. Alternatively, spontaneous ventilation can be maintained during laryngoscopy by insufflating continuous 100% oxygen through the side-port of the suspension laryngoscope. As with rigid bronchoscopy, a TIVA technique is preferred. Capnography is impossible during jet ventilation or insufflation techniques. If it is essential that $P_{\text{CO}_2}$ be monitored, transcutaneous carbon dioxide monitoring will provide a reasonable estimate.

If suspension laryngoscopy is used in combination with the $\text{CO}_2$ laser, all usual laser precautions should be strictly followed. The child’s eyes should be securely covered with wet saline gauze, and all skin surfaces are completely covered with sheets or drapes. If the endotracheal tube remains within the airway during the laser treatment, it must be completely wrapped with aluminum tape or a commercially available laser tube should be used. If auffed endotracheal tube is used, the cuff should be filled with water or saline. Some anesthesiologists inject methylene blue into the saline that goes into the cuff to better detect its breakage by the laser. Oxygen concentrations should be as low as possible and $\text{N}_2\text{O}$ should be avoided to minimize combustibility.

Tracheostomy

The term given to creating a hole in the trachea is a matter of debate, with the names tracheotomy and tracheostomy used interchangeably. In general, tracheotomy is the temporary surgical cutting of the trachea through the anterior neck tissues, whereas tracheostomy entails a more permanent opening into the trachea and placement of the tracheostomy tube.

Over the last decade, there has been a decrease in the number of pediatric tracheostomies being performed, largely due to improvements in airway management by pediatric anesthesiologists. However, with an increase in the length of survival of children with complex medical problems, a new population of patients requiring tracheostomy is emerging. Several studies have shown that once a tracheostomy is placed, the duration that it is left in place has increased over time due to the increased number of chronically ventilated children. A recent trend shows that the procedure is being performed in younger children, with a peak incidence in patients aged under 12 months.

The three most common indications for a tracheostomy in children are: (1) prolonged mechanical ventilation
diameter determines the actual airway size. The diameter of the tube should be large enough to allow adequate air exchange, easy suctioning, and clearance of secretions. If the indication for tracheostomy is assisted ventilation, the size of the tube should be adjusted to prevent excessive air leak. Predictors of the appropriate tube size include the child’s age and the size of a preexisting endotracheal tube. Too large a tube will compromise the capillary flow in the tracheal wall, which may result in mucosal ulceration and development of fibrous stenosis. Overinflation of a cuffed tracheostomy tube for a prolonged period may produce similar injuries. This complication may be avoided by selecting the proper sized tracheostomy tube (Table 29-2) and adjusting the cuff pressure to less than 20 cmH₂O. The choice of the tube size is also influenced by visualizing the size of the tracheal lumen.

The length of the tube is important, especially in neonates and infants. A tube that is too short may result in accidental decannulation or the development of a false passage. If a tube is too long, the tip may abrade the carina or rest in the right main bronchus. Some plastic tubes may be cut to the desired length. Extra-long custom-made tubes may be helpful in unusual situations, such as tracheomalacia or tracheal stenosis, to span the involved area.

Unless airway obstruction is immediately life-threatening, pediatric tracheostomy procedures should be performed in the operating suite. This creates a well-controlled environment for the child and the personnel performing the procedure. The operating suite provides optimal illumination, proper positioning of the child, and expert nursing care. In addition, a full range of laryngoscopes and bronchoscopes are available to control the airway if necessary.

In children with an indwelling endotracheal tube, the choice of induction and maintenance of general anesthesia is unimportant. However, if the tracheostomy is being performed for acute airway obstruction, principles of difficult airway management will apply (Chapter 18). Prior to performing the procedure, the surgeon and anesthesiologist should discuss the method of choice for obtaining and securing the airway. All alternatives should be discussed in the event that the child cannot be intubated successfully. It is preferred to perform the tracheostomy with the child intubated under general anesthesia with paralysis. In certain situations of severe upper airway obstruction, it may be necessary to perform the tracheostomy with mild sedation and infiltration of local anesthesia.

The tracheostomy is performed supine with the child’s neck extended using a shoulder roll. The child should be breathing 100% oxygen in anticipation of a temporary interruption of ventilation. If a nasogastric tube is present it should be removed so as not to alter normal neck anatomy. Lidocaine with epinephrine is infiltrated into the subcutaneous tissue one to two fingerbreadths above the sternal notch. A horizontal skin incision is then made...
at the same site. A vertical midline dissection is performed to expose the tracheal rings. Traction sutures are placed in a paramedian position at the level of the second or third tracheal ring, to rapidly open the airway should accidental decannulation occur before the tract is established. The trachea is incised vertically in the midline to expose the underlying endotracheal tube. While directly observing the endotracheal tube, the anesthesiologist gradually pulls it back to just above the incision as the surgeon inserts the tracheostomy tube. The anesthesia breathing circuit is then connected to the tracheostomy tube; correct placement is confirmed by listening for bilateral breath sounds and observing a normal capnographic tracing. Prior to these final confirmations, the endotracheal tube should never be completely withdrawn out of the trachea. Flexible bronchoscopy is then performed to identify the distal position of the tracheostomy tube. Proper adjustment or possible replacement of the tracheostomy tube with a different size is done at this stage. The previously placed endotracheal tube is removed just prior to leaving the operating room or after arrival at the intensive care unit. A postoperative chest radiograph is obtained to further confirm tube position and rule out pneumothorax.

Postoperatively, humidified air by collar or ventilator is provided to prevent excessive dryness and thickening of tracheal secretions. The first tracheostomy tube change is done on the fifth to seventh postoperative day after a well-formed tract has been established. The traction sutures are also removed at this time.

Anesthesiologists should be aware of the various complications related to pediatric tracheostomy. Bleeding can occur from superficial tissues, thyroid vessels, or vascular anomalies such as a high-riding innominate artery, and can obstruct the surgeon’s view of the opened trachea. Air entry into the subcutaneous tissues may cause a pneumomediastinum, pneumothorax, subcutaneous emphysema, or any combination of those. Anatomic injury to the neurovascular structures in the neck, including the recurrent laryngeal nerve, can also occur. During placement, the tracheostomy tube can be unintentionally placed into a false lumen adjacent to the trachea, or into the esophagus. For these reasons, the endotracheal tube should never be fully removed before final confirmation that the tracheostomy tube is functional.

### LOWER AIRWAY SURGERY

**Bronchial Foreign Body**

A variety of different types of edible and inedible foreign bodies commonly become lodged in the distal bronchial tree. Toddlers are most affected because of their underdeveloped ability to coordinate swallowing of small food items such as peanuts. Bronchial foreign bodies are likely to cause distal airway obstruction with development of emphysema, atelectasis, and pneumonia. Children may present with a respiratory illness that runs the gamut from tachypnea and fever to respiratory failure and hypoxemia. A bronchial foreign body is suspected when a toddler presents with the sudden onset of respiratory distress that usually begins with a choking episode. The foreign object may or may not be observed. Confirmation of the diagnosis consists of radiological demonstration of the foreign body if it is radiopaque, or unilateral emphysema from a ball-valve effect of the distal obstruction. An aspirated peanut will exacerbate the condition by causing a lipoid pneumonitis.

This procedure is usually considered a surgical emergency. Preoperative assessment should be focused on determining respiratory function, administration of antibiotics, and bronchodilator therapy if bronchospasm is present. An intravenous catheter should be inserted. Intravenous midazolam can be titrated to achieve anxiolysis in the preoperative holding area under direct supervision of the anesthesiologist. An anticholinergic agent should also be administered. A rapid sequence induction and tracheal intubation is indicated if a full stomach is suspected. Induction and maintenance of general anesthesia is the same as described above for rigid bronchoscopy, with a choice between spontaneous or controlled ventilation.

### NECK SURGERY

**Thyroglossal Duct Cyst**

A thyroglossal duct cyst is a small collection of fluid in the soft tissue of the midline of the neck. It is believed to be a remnant of the connection between the tongue and the thyroid gland in fetal life. During childhood it can become infected and enlarged, and requires excision. These children are usually otherwise healthy. Preoperative assessment, and induction and maintenance of general anesthesia, are no different from usual. The anesthesiologist may wish to place a towel wrap around the head with which to secure the endotracheal tube over the forehead. The child is positioned similarly to tracheostomy with the neck extended for a transverse midline incision. The anesthesiologist may be asked to depress the base of the tongue to move the cyst to facilitate surgical identification. Surgical risks include unintentional trauma to vascular or airway structures in the neck. Postoperative concerns include hematoma formation with subsequent airway compression.

**Branchial Cleft Cyst**

Branchial cleft cysts are found on the side of the neck and develop from a failure of involution of one of the
branchial clefts during embryonic development. These children are otherwise healthy; perioperative and postoperative anesthetic implications are essentially the same as for the thyroglossal duct cyst.

**Neck Mass Biopsy and Excision**

When unclassified neck masses in children do not respond to conventional antibiotic therapy, an excisional biopsy is indicated to rule out malignancy or (rarely) tuberculosis. The vast majority of these cases are straightforward; the anesthetic implications are described above. However, when a lymphoma is suspected, the anesthesiologist must be aware that there may be an occult anterior mediastinal mass that carries the potential for life-threatening airway obstruction following induction of general anesthesia (see Chapter 8). Preoperative symptoms that are suggestive of an anterior mediastinal mass include coughing or dyspnea in the supine position that is relieved when the child assumes the sitting or prone positions.

**Cystic Hygroma**

Another name for a cystic hygroma is a lymphangioma. It is a malformation of lymphatic vessels in and around the neck region. They are strongly associated with Turner syndrome, trisomy 21 (Down syndrome), trisomy 18 (Edwards syndrome), and Noonan syndrome, although many otherwise normal children are affected. Cystic hygromas are often found at birth and tend to enlarge during early childhood. The majority of children present for surgical excision for cosmetic reasons. The occasional child will present for reduction and/or tracheostomy due to respiratory distress from airway compression (Fig. 29-7). Cystic hygromas notoriously grow inward and compress the airway. The preoperative assessment should always include MRI examination to delineate its spread and evaluate airway patency. A hemoglobin level and type-and-screen should be obtained preoperatively if an extensive dissection and excision is planned, or if the mass is located near the vascular structures of the neck. Induction

**Article To Know**


The pediatric anesthesia community was shocked with the report of an intraoperative death of an otherwise healthy 4-year-old undergoing routine adenoidectomy. The course of events that led to this tragedy began with the intraoperative topical instillation of phenylephrine into the child’s nasopharynx, and subsequent treatment of severe hypertension with a beta-blocker (labetalol). This publication summarizes the findings of a panel that was convened by the New York State Department of Health to investigate this and other similar cases, to determine the mechanism of cause of death, and to recommend guidelines for future use of phenylephrine in the operating room.

Although it is becoming less frequent, some surgeons continue to use phenylephrine (0.25–1%) as a topical vasoconstrictor during upper airway surgery. Total absorbed doses are difficult to calculate. However, there are a number of published reports of systemic absorption of topical phenylephrine that resulted in severe hypertension. The New York State panel that reviewed these cases noted a recurrent pattern associated with poor outcomes: the development of severe, refractory pulmonary edema and cardiac failure following treatment with beta-blockers. Table 29-3, taken from this article, details these cases.

<table>
<thead>
<tr>
<th>Patient #</th>
<th>Age (years)</th>
<th>Phenylephrine (%)</th>
<th>Hypertensive Treatment</th>
<th>Pulmonary edema</th>
<th>Cardiac Arrest</th>
</tr>
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<tbody>
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<td>3</td>
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<td>No</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>0.5</td>
<td>L, AD</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>0.25</td>
<td>L</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>??</td>
<td>L, AD</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
<td>1.0*</td>
<td>AD, E, Ca</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>0.5*</td>
<td>L, AD</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>56</td>
<td>1.0*</td>
<td>AD</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>40</td>
<td>1.0*</td>
<td>AD</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>9</td>
<td>47</td>
<td>0.5*</td>
<td>L, AD</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*Lidocaine with 1:100,000 epinephrine was also injected into the surgical field.
L, labetalol; AD, anesthesia deepened; E, esmolol; Ca, calcium-channel blocker.

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Phenylephrine administration causes stimulation of alpha-1 receptors and increases total peripheral resistance by vasoconstriction. Administration of beta-blockers will impair the heart's ability to maintain cardiac output by increasing contractility and heart rate. This cardiac depression, coupled with the shifting of blood into the pulmonary vasculature, results in pulmonary edema, as seen in the patients described in the article.

The following are the author's recommendations for use of phenylephrine in children; they are adapted from the Phenylephrine Advisory Committee's guidelines:

1. Phenylephrine should not be used as a topical vasoconstrictor during airway procedures in children. Oxymetazoline, 0.025%, is equally effective and is not associated with adverse effects in children.
2. If phenylephrine is used in children, the initial dose should not exceed 20 µg/kg. During its use, blood pressure and pulse should be closely monitored.
3. Phenylephrine-induced hypertension is transient and benign in otherwise healthy children. It should not be initially treated unless it persists or results in electrocardiographic abnormalities or pulmonary edema. It is reasonable, however, to transiently increase the concentration of inhalational agent while closely monitoring hemodynamic status.
4. Antihypertensive agents that are direct vasodilators or α-receptor antagonists (e.g., nitroprusside, hydralazine) are appropriate treatments. Beta-blockers and calcium-channel blockers should be avoided since their use is associated with worsening of cardiac output and development of pulmonary edema.

and maintenance of general anesthesia is practitioner dependent and will vary with the severity of the mass and the degree of airway obstruction. Principles of management of the difficult airway will apply if upper airway obstruction is suspected. Intraoperative concerns include blood loss, fluid management, and hypothermia if the dissection is extensive, and the possibility of nerve monitoring. A temporary urinary catheter should be placed if the procedure is expected to last more than 3–4 hours.

ADDITIONAL ARTICLES TO KNOW


Anesthesia for Pediatric ENT Surgery

**Box 29-1 LMA for Tonsillectomy**

**Advantages**
- Easy to insert
- Allows for lighter level of general anesthesia
- Smoother emergence without tracheal stimulation
- Can be removed at completion of procedure prior to patient regaining full consciousness
- Decreased incidence of postoperative sore throat

**Disadvantages**
- May retract more cephalad in pharynx and obscure surgical view
- Appropriate size for child may not fit under surgeon’s mouth-opening device
- May not completely protect against secretions entering the glottic opening

**Box 29-2 Anesthesia Protocol for Tonsillectomy at The Children’s Hospital of Philadelphia**

**Premedication**
- Oral midazolam 0.5 mg/kg; maximum dose 10 mg (for small children with sleep apnea, some anesthesiologists choose to halve this dose)
- Oral acetaminophen 10–15 mg/kg

**Induction**
- Sevoflurane (8% and adjusted downward as child loses consciousness)
- N₂O, 70% in oxygen - discontinued when intravenous access is established
- Vecuronium 0.1 mg/kg
- Morphine 0.075–0.125 mg/kg

**Maintenance**
- Desflurane (concentration titrated to hemodynamic variables)
- N₂O, 70% in oxygen

**Emergence**
- Reversal of muscle relaxant with neostigmine and atropine or glycopyrrolate
- Extubation when awake

**Adjunct Intraoperative Therapy**
- Ondansetron 1–2 mg
- Dexamethasone 0.5 mg/kg; maximum dose 10 mg

**Postoperative**
- Morphine 0.05 mg/kg titrated to pain relief or onset of sleep
- Ondansetron 1–2 mg for continued emesis
- Oxygen as needed to maintain SpO₂ > 94% prior to discharge from PACU

*All medications are administered intravenously, except for premedication.*

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**Table 29-1 Size Characteristics of the Rigid Bronchoscope**

<table>
<thead>
<tr>
<th>Size (cm)</th>
<th>Length (mm)</th>
<th>ID (mm)</th>
<th>OD (mm)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>20</td>
<td>3.5</td>
<td>4.2</td>
<td>Premature</td>
</tr>
<tr>
<td>3.0</td>
<td>20, 26</td>
<td>4.3</td>
<td>5.0</td>
<td>Premature, newborn</td>
</tr>
<tr>
<td>3.5</td>
<td>20, 26, 30</td>
<td>5.0</td>
<td>5.7</td>
<td>Newborn to 6 months</td>
</tr>
<tr>
<td>3.7</td>
<td>26, 30</td>
<td>5.7</td>
<td>6.4</td>
<td>6–12 months</td>
</tr>
<tr>
<td>4.0</td>
<td>26, 30</td>
<td>6.0</td>
<td>6.7</td>
<td>1–2 years</td>
</tr>
<tr>
<td>5.0</td>
<td>30</td>
<td>7.1</td>
<td>7.8</td>
<td>3–4 years</td>
</tr>
<tr>
<td>6.0</td>
<td>30, 40</td>
<td>7.5</td>
<td>8.2</td>
<td>5–7 years</td>
</tr>
<tr>
<td>6.5</td>
<td>43</td>
<td>8.5</td>
<td>9.2</td>
<td>Adult</td>
</tr>
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</table>

ID, inner diameter; OD, outer diameter.

<table>
<thead>
<tr>
<th>Cannula</th>
<th>Approx. French</th>
<th>Inner Diameter (mm)</th>
<th>Outer Diameter (mm)</th>
<th>Overall Length</th>
</tr>
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<tr>
<td><strong>Endotracheal tube</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
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</tr>
<tr>
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<td>3.6</td>
<td>12 cm</td>
</tr>
<tr>
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<td>3.0</td>
<td>3.0</td>
<td>4.3</td>
<td>14 cm</td>
</tr>
<tr>
<td>3.5</td>
<td>3.5</td>
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<td>4.9</td>
<td>16 cm</td>
</tr>
<tr>
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<td>4.0</td>
<td>5.6</td>
<td>18 cm</td>
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<td>6.0</td>
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<tr>
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<td>5.3</td>
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</tr>
<tr>
<td>5.0</td>
<td>22</td>
<td>5.0</td>
<td>7.3</td>
<td>44 mm</td>
</tr>
<tr>
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<td>24</td>
<td>5.5</td>
<td>8.0</td>
<td>46 mm</td>
</tr>
<tr>
<td><strong>Franklin</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
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</tr>
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<td>3.5</td>
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<td>44 mm</td>
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<td>4.0</td>
<td>6.0</td>
<td>44 mm</td>
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<td>48 mm</td>
</tr>
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<td></td>
<td>5.0</td>
<td>8.0</td>
<td>51 mm</td>
</tr>
<tr>
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<td>5.5</td>
<td>8.5</td>
<td>54 mm</td>
</tr>
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<td>3.5</td>
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<td>44 mm</td>
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<tr>
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<td></td>
<td>4.5</td>
<td>7.1</td>
<td>48 mm</td>
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<td>5.0</td>
<td>7.7</td>
<td>50 mm</td>
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<tr>
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<tr>
<td>00 Neonatal</td>
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<td>4.5</td>
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<td>00 Pediatric</td>
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</tr>
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<td>3.4</td>
<td>5.0</td>
<td>32 mm</td>
</tr>
<tr>
<td>0 Pediatric</td>
<td></td>
<td>3.4</td>
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<td>40 mm</td>
</tr>
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<td>34 mm</td>
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<td>1 Pediatric</td>
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<td>41 mm</td>
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<tr>
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<td></td>
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</tr>
<tr>
<td>3 Pediatric</td>
<td></td>
<td>4.8</td>
<td>7.0</td>
<td>44 mm</td>
</tr>
<tr>
<td>4 Pediatric</td>
<td></td>
<td>5.5</td>
<td>8.0</td>
<td>46 mm</td>
</tr>
</tbody>
</table>

<sup>a</sup>The endotracheal tubes are marked with the inner diameter, usually with the outer diameter, and with the length.

<sup>b</sup>The Bivona tube is manufactured by the Bivona Corporation of Gary, IN. Both the inner and outer diameters are marked on the tubes.

<sup>c</sup>The Franklin tube is of the Great Ormond Street design, manufactured in England and distributed by Inmed Corporation Norcross, GA. The tubes are stamped with just the inner diameter.

<sup>d</sup>The Shiley tube is manufactured by Shiley Laboratories, Irvine, CA. The tubes are stamped with the size and inner and outer diameters.

Figure 29-1 Anesthetic management of myringotomy tube placement. While maintaining mask ventilation, the anesthesiologist turns the patient's head to the side to allow the surgeon to perform the myringotomy and insertion of ventilating tubes by visualizing the ear drum with a microscope. Upper airway obstruction commonly occurs while the child's head is turned.

Figure 29-2 Tonsillectomy positioning. The OR table is turned 90 degrees away from the anesthesiologist. The surgeon inserts a mouth-opening gag (a MacGiver device is shown in this photo) that stabilizes the oral RAE endotracheal tube on the chin. During mouth opening, the endotracheal tube can become compressed or kinked, or unintentional trauma to the mouth or lips may occur.

Figure 29-3 During dental and oral surgery procedures, a nasal RAE endotracheal tube is secured to the forehead using a head wrap. Care is taken to ensure that the bend of the tube does not abut against the tip of the nose, to prevent compression ischemia.

Figure 29-4 Rigid bronchoscope. The distal end of the rigid bronchoscope is blunt, and the proximal end contains a ventilation side-port (D) that attaches to the standard anesthesia breathing circuit. A thinner telescope with an optical eyepiece (B) is placed coaxially through the proximal end and allows for magnified and illuminated visualization of the airway. The rigid bronchoscope as shown contains additional ports for attachment of a light source (A) and a suction port (C).
Figure 29-6  Suspension laryngoscopy. The child’s head and neck are fixed with the suspension laryngoscope to provide optimal visualization of the larynx.

Figure 29-5  Anesthesia for rigid bronchoscopy. Once the child is adequately anesthetized, and just prior to performing rigid bronchoscopy, the OR table is turned 90 degrees away from the anesthesiologist, while mask ventilation is continued by the anesthesiologist from a side position or by an assistant at the head of the table until the surgeon is prepared to instrument the airway.

Figure 29-7  Large cystic hygroma. This child required tracheostomy to relieve airway compression from a large cystic hygroma.