The potentially difficult airway

CATHY MASTROPIETRO, CRNA, MEd.
Youngstown, Ohio

Airway obstruction can occur along any portion of the respiratory tract. Obstruction may be caused by congenital abnormalities, by pathophysiologic states or by acute trauma. The approach to management of these patients depends on whether one is dealing with a pediatric or adult airway, on the location of the tumor, on the emergent nature of the obstruction, or on the expected degree of respiratory compromise following induction.

Airway obstruction can occur at any time during administration of a general anesthetic, particularly in patients with predisposing structural abnormalities of the airway. It has been documented that 25% of preventable anesthetic deaths are due to some form of airway mismanagement.

Ideally, the anesthetist should be able to identify the patient with a potential airway disorder prior to induction of anesthesia, and thus be ready to employ special techniques to provide adequate gas exchange. These techniques may range from alteration of head position, to awake intubation or fiberoptic bronchoscopy, to tracheostomy or cardiopulmonary bypass. Immediate diagnosis of the cause of airway obstruction is essential to institute appropriate treatment. This discussion focuses on the etiology and management of airway obstruction specific to the pediatric and adult patient.

Etiology of upper and lower airway obstruction

There are many causes of upper and lower airway obstruction (Table I). Close cooperation between the laryngologist and/or surgeon and anesthetist may mean the difference between a smooth and a stormy anesthetic induction.

Congenital anomalies. Congenital anomalies may involve any part of the respiratory tract, but the most commonly underestimated deformities occur in first and second brachial arch anomalies. Anatomical problems such as microstomia, micrognathia, macroglossia, short thick neck, and unusual angulation of the larynx are frequent. Any of these conditions can make it difficult to fit a laryngoscope in the mouth or to angle it properly. Mask fits are often impossible with such conditions, and short necks make rapid tracheostomy difficult.

Infection. Infections of the oral cavity frequently require surgical intervention. Difficulty with intubation or mask ventilation often accom-

| Table I |
| Causes of airway obstruction |
| 1. Congenital anomalies |
| 2. Infection |
| 3. Tumor |
| 4. Trauma |
| 5. Foreign body |
| 6. Iatrogenic |
panies these situations. Infections of the tongue, oral cellulitis, or pharyngeal or tonsillar abscesses can completely obstruct the airway simply by virtue of their size. The most common infections in children are acute laryngitis, epiglottitis and croup; induction in these patients may be complicated by laryngospasm or bronchospasm. Selection of appropriate endotracheal tube size to minimize sub-glottic trauma is essential.

Tumors. Tumors of the oral cavity, pharynx and larynx may limit motion and cavity size and may substantially distort anatomical features, obscuring landmarks. Tumors below the larynx may compress the trachea, making usual intubation techniques inadequate for bypassing the obstruction.

Trauma. Trauma may be either internal from ingestion of toxic substances, inhalation burns or from blunt injury, or external secondary to facial or neck injury.

Foreign body. Foreign bodies in the hypopharynx, larynx, or lower airway and esophagus require special considerations to avoid converting a partial obstruction into a complete obstruction, or to avoid moving the foreign body to a less desirable place.

Iatrogenic. Severe allergic reactions, postoperative bleeding, laryngeal edema, laryngospasm, bronchospasm or aspiration all create significant airway management problems.

Assessment of airway

Patients with airway obstruction can be categorized into three groups: patients in extremis with total or near total obstruction associated with hypoxia, hypercarbia, delirium or unconsciousness; patients who have obvious respiratory distress such as stridor, dyspnea, intercostal retraction or tracheal tug, but who are alert and cooperative; and patients with impending distress whose respiratory difficulties occur after medication or manipulation.

A careful history regarding the patient's sleep habits can give some indication of the degree of compromise. The quality of the voice is helpful in determining location of the lesion. A scratchy voice is suggestive of a glottic lesion, whereas a muffled voice is characteristic of a subglottic lesion. While not always possible, extensive preoperative evaluation including blood gas analysis, pulmonary function tests, radiographic exams or computed tomography (CT) scans may be extremely helpful in predicting the extent of the disease and the degree of airway compromise.

Management of the difficult airway

The prime objective in the management of the compromised airway is to gain control of the airway by bypassing the obstruction, either from above the larynx with an endotracheal tube or from below through performance of a tracheostomy.

The patient in extremis should never be premedicated or anesthetized prior to establishment of an airway, even if cricothyrotomy is the only means of establishing an airway. Sedatives and hypnotics should be avoided even in small doses because they can turn a partial obstruction into a total obstruction. Inhalation anesthesia without the utilization of muscle relaxants appears to be the most acceptable technique. The rate of induction should be sufficiently rapid initially to minimize the risk of excitement, but as induction proceeds and relaxation of muscle tone becomes more evident, the rate should be slowed to allow assessment of any developing loss of airway.

If the patient is in a sitting position, progression to the supine position should be slow and attempted only after anesthetic stages are obtained. Antisialogogues are useful for controlling excessive salivation. Laryngoscopy and intubation must not be performed until adequate planes of anesthesia are established. The necessary anesthesia equipment must be available in the event of difficulty with airway management or tracheal instrumentation. Additional equipment such as extra and varying size blades and endotracheal tubes, forceps, stylets, fiberoptic bronchoscope, ventilating bronchoscope, tracheostomy equipment and in some instances cardiopulmonary bypass equipment should be available. The decision to perform a tracheostomy is based on the friability of the larynx, estimation of size of the glottic opening or visibility of anatomical landmarks.

No matter which technique is employed, be it awake intubation, inhalation induction or local infiltration and tracheostomy, it must be remembered that these patients are extremely anxious and need constant reassurance. Lack of stimulation is important during the induction period. The patient should not be questioned once induction has begun, as there is nothing more frustrating for the anxious patient than to fight the depressant effects of an anesthetic in order to answer a question that he feels is pertinent to his welfare.

Pediatric versus adult airway

Anatomic and physiologic differences exist when comparing the pediatric airway with the adult airway (Table II). The infant tongue is large in proportion to the rest of the oral cavity, and thus more easily obstructs the airway. Manipulation and stabilization is more difficult than with the adult.
The infant larynx is located approximately at C3-4 then rests at C4-5 after adulthood is reached. Visualization may be made easier by use of a straight blade.

The infant epiglottis is short, narrow and angled away from the trachea, whereas the adult epiglottis is flatter, more flexible and parallel to the trachea. The narrowest part of the infant airway is the cricoid ring, which is a complete cartilaginous ring whose posterior plate tilts anteriorly, causing the infant larynx to be funnel-shaped with its apex at the cricoid ring. In the adult, the narrowest section is the rima glottis. The infant cords slant with the anterior point being lower than the posterior point, compared to the adult cords which are straight and flat.

The mucous membranes of the airway are lined with both squamous and columnar cells. The squamous epithelium lines the area above the cords and is bound tightly to fibrous tissue and cartilage. The columnar epithelium, found between cords, is loosely attached in the pediatric airway and, therefore, is subject to edema due to irritation or rebound engorgement following extubation or overhydration. Figure 1 illustrates the differences between the infant and adult glottis.

In the pediatric patient a reduction in airway diameter requires that the pressure to produce a given flow be increased according to Poiseuille's equation of laminar flow. If the radius of an airway is decreased by 50%, the pressure to maintain flow must be increased by 16-fold, and since turbulent flow is related to the reciprocal of the radius of the fourth power, the child with a stenotic lesion and turbulent flow must significantly increase the driving force of the air passing through the upper airway. Since the infant's tissues are softer and the tissue planes looser and more compressible than those in the adult, attempts to increase this driving force by using accessory muscles may cause additional airway collapse. A further imbalance in the \( \text{O}_2 \) supply/demand ratio is created when an airway obstruction increases breathing effort in a child.

![Image](image_url)

**Figure 1**
Infant glottis (× 6), left, and adult glottis, right. Note the soft, edematous appearance of infant tissue and the folded, omega shape (Ω) of the epiglottis.


| Table II |
|---|---|
| **Pediatric vs. adult airway** | **Infant** | **Adult** |
| Larynx | C3-4 | C4-5 |
| Epiglottis | short, narrow | flat |
| | slants away from trachea | parallel to trachea |
| Trachea | narrowest at cricoid ring | narrowest at rima glottis |
| | loosely attached | |
| | columnar epithelium | |
| Cords | slant anteriorly | straight |
| Resistance of nasal passages | 25% | 60% |
| Work of breathing | accounted for by small airway resistance | accounted for by nasal passage resistance |
| \( \text{O}_2 \) consumption | 4-6 ml/kg/min | 2-3 ml/kg/min |

February 1988/Vol. 56/No. 1
whose oxygen consumption is higher than an adult's and whose respiratory reserve is lower.\textsuperscript{5}

Newborns and infants who weigh less than 10 lb can be intubated awake. The head and shoulders need to be stabilized, and downward pressure exerted on the shoulder counteracts the lifting force of the laryngoscope. Nasal intubations should be performed under anesthesia and direct vision with use of muscle relaxants.

Blind nasal intubation is possible in children who are extremely cooperative or who have been anesthetized. The incidence of nasal hemorrhage is high with this technique and is difficult to control once started. A blind nasal approach may be difficult due to the anatomic relationship of the larynx to the pharyngeal cavity, and may require the use of a Magill forceps.\textsuperscript{4} Intravenous ketamine may be helpful in accomplishing a blind nasal intubation since laryngeal reflexes are maintained and analgesia for nose discomfort is provided with its use.

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<tr>
<th>Disorders of the nose in the pediatric patient</th>
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<td>Airway management difficulties differ in the child and adult, and the degree of compromise is also influenced by the anatomical location of the obstruction (Table III). The abnormality can be located either in the nose, oral cavity, head and neck, pharynx, glottis and larynx, or trachea and bronchus. In the child, many of these abnormalities are congenital.</td>
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<td>Infants are nose breathers, and any condition that interferes with nasal air flow can lead to respiratory obstruction. Choanal atresia is a term used to describe the bony occlusion of one or both posterior nares or choanae. It can be life threatening in infants unless measures are taken to keep the mouth open by use of an oral airway, or surgery is performed to establish a nasal airway.\textsuperscript{4} Surgical intervention is performed in the first few days with bilateral atresia, but the condition may go unnoticed for months or years if the atresia is unilateral.</td>
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<td>Fractured noses and adenoid hyperplasia present problems in children, again due to their dependence on the nose for breathing. The patient with excessively large adenoids can obstruct completely when sleeping or sedated.</td>
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<td>Cleft lip</td>
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\textbf{Table III}  
Disorders classified according to anatomic location

\textbf{Disorders of the nose}  
Choanal atresia  
Fractures  
Adenoid hyperplasia  
Trauma

\textbf{Disorders of the oral cavity}  
Pierre Robin syndrome  
Downs syndrome  
Cleft lip  
Infections  
Trauma

\textbf{Disorders of the head and neck}  
Klippel-Feil syndrome  
Rheumatoid arthritis  
Coronoid hyperplasia

\textbf{Disorders of the pharynx}  
Cystic hygroma  
Weavers syndrome  
Hurlers syndrome  
Abscesses  
Teratoma

\textbf{Disorders of the glottis and larynx}  
Juvenile laryngeal papillomatosis  
Acute epiglottitis  
Laryngotracheobronchitis  
Bronchiolitis  
Bleeding tonsillectomy and adenoidectomy  
Foreign body aspiration  
Tumors  
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Crushed larynx

\textbf{Disorders of the trachea and bronchus}  
Substernal thyroid  
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Infections  
Tracheoesophageal fistula  
Diaphragmatic hernia  
Lacerated trachea

\textit{Pierre Robin Syndrome.}  
Pierre Robin Syndrome is a congenital micrognathia and glossoptosis. A total of 50\% of the cases are associated with cleft palate.\textsuperscript{1} The tongue is posteriorly displaced and may be hyperplastic. The supine position of the patient causes obstruction of the oropharynx and nasopharynx, preventing normal breathing. Airway problems are generally compounded by aspiration. Glossopexy, by creation of a lip tongue adhesion, is performed because of life-threatening obstructive
episodes or because of chronic aspiration and pneumonia. The anesthetic protocol includes avoiding sedatives that may obviously enhance the airway difficulty, such as barbiturates and benzodiazepines, and administering anticholinergics to reduce copious secretions. The infant is generally brought to the operating room suite in the prone position and should be preoxygenated in this position. When the infant is turned to the supine position, a severe obstruction can occur and a surgeon should be available for tracheostomy should it be necessary. Oxygen should be insufflated during intubation because the larynx is frequently anterior and exposure is difficult, often requiring a blind nasal intubation.

**Down’s Syndrome (Trisomy 21).** Down’s Syndrome is familiar to the anesthetist for such children commonly visit the surgical suite for dental rehabilitation, herniorrhaphy or repair of cardiac defects. The Down’s Syndrome child has characteristic features including a round head and face, an open mouth and a protruding tongue, which may interfere with mask fit and intubation. Poor dentition can lead to tooth dislodgement during intubation.

**Cleft lip.** Twenty-five percent of cleft lips are bilateral, and 85% of bilateral clefts are associated with cleft palate. There is usually a family history of the condition and the incidence is twice as common in males. The concern of the anesthetist for the patient undergoing cheiloplasty is to maintain a patent airway without distorting the lip. Because the adequacy of an airway and ease of intubation are never assured, muscle relaxants should be avoided. Care must be taken to protect the tissues involved in the cleft during intubation. Also, if there is a cleft palate, dental packs may be necessary to fill the defect so that the laryngoscope blade is not lost in the cleft.

The use of a Mallinckrodt RAE tube is advocated with these procedures because it offers many advantages: the black line on the tube indicates tube position just above the carina, the long length of the tube gives added protection against inadvertent extubation when the head is extended and also aids in the prevention of lip distortion, and the Murphy eye on each side of the tube assures ventilation if the tube is positioned too deep.

**Disorders of the pediatric head and neck**

Mobility of the neck and opening of the mouth are important for the alignment of the tracheo-oral axes and visualization of the glottis. When a patient lies flat on the bed or operating room table, the oral, pharyngeal and tracheal axes pass through three divergent planes. Placing a towel under the occiput and extending the atlanto-occipital joint results in alignment of the oral, pharyngeal and tracheal axes (Figure 2).

Disabilities in patients with various forms of arthritis, both rheumatoid and juvenile, congenital abnormalities such as Klippel-Feil Syndrome and coronoid process hyperplasia are conditions that
require testing of the patient's ability to move his neck and open his mouth.²

**Klippel-Feil Syndrome.** Klippel-Feil syndrome is a congenital fusion of two or more vertebrae which results in a short wide neck with limitations in its mobility. Surgical treatment may include a Z-plasty to reduce wide skin folds, with muscular and facial release to improve mobility.⁴

**Disorders of the pediatric pharynx**

Masses of the pharynx can result in complete airway obstruction after muscle relaxation, and inability to identify the glottis may require an emergency tracheostomy.² Tumors or lesions of the tongue, cellulitis and mandibular or tonsillar abscesses can also cause pharyngeal obstruction.

*Cystic hygroma (cervical).* Cystic hygroma is a congenital tumor of lymphatic origin commonly found in the neck. Careful evaluation of the trachea and main stem bronchi is necessary to avoid airway obstruction during induction.³ Large tumors may cause anatomic distortion and make identification of landmarks difficult. The child may either be intubated awake or given an inhalation induction; the decision is based on the degree of difficulty anticipated.

Assisted ventilation is advocated so that the anesthetist will be alerted to changes in respiratory compliance with tumor manipulation. The degree of difficulty that occurs with tumor removal dictates the method of postoperative airway management. If the tumor is resected from the trachea and its nerves, or into the floor of the mouth or larynx, or into the chest with the possibility of pneumothorax, prolonged intubation is often desired.¹

**Weavers Syndrome.** Weavers syndrome is a rare overgrowth syndrome that begins prenatally with accelerated skeletal maturation and unusual facies.⁷ The position of the larynx is a major problem: the epiglottis and cords may be invisible and may require awake intubation with local anesthetic spray or transtracheal block if the patient is cooperative, blind nasal intubation under general anesthesia, or the use of a fiberoptic bronchoscope. Observing the depth of the mandible can help to determine the difficulty of performing laryngoscopy. A receding lower jaw, short muscular neck, full set of teeth, protruding incisors and poor mobility of the temporomandibular joint are frequently occurring symptoms.⁸ Small bowel obstruction is commonly associated with Weavers Syndrome, and aspiration can be a problem during emergency surgery.

**Hurler’s Syndrome.** Patients with Hurler's Syndrome have been described as presenting the worst airway problems in pediatric anesthesia.⁴ Hurler’s Syndrome (gargoylism) is a prototype of mucopolysaccharidosis, which is a group of inheritable connective tissue disorders in which there is deposition of abnormal amounts of mucopolysaccharides in the body tissues. Heparin sulfate, dermatin sulfate and keratin sulfate, all mucopolysaccharides, infiltrate the soft tissues of the oropharynx—especially the tongue and floor of the mouth, epiglottis, aryepiglottic folds and the tracheal wall.⁶

The neck is short and there may be flaring of the lower rib cage, possibly due to hepatosplenomegaly. The cardiovascular system is also affected by deposits in the coronary arteries and valves. Mental retardation and hydrocephalus are associated with this disease.

These children are highly susceptible to middle ear infection due to abnormalities of nasopharyngeal anatomy, and they are frequent subjects for ENT procedures. Endoscopy and intubation can be extremely difficult because the pharyngeal structures and larynx may be impossible to identify and the patient's own respiratory efforts may be the only guide to the location of the glottic opening. It is commonly believed that the incidence of difficulty in managing the airway increases with age, often making emergency tracheostomies necessary. Full atropine administration is recommended to control excessive secretions.

*Abscesses.* Abscesses or cellulitis of the tongue or tonsils may be severe enough to make oral intubation difficult or impossible. Ludwig’s angina is massive submandibular cellulitis in which the airway may be inaccessible. Either awake nasal intubation or inhalation anesthesia is recommended as the technique of choice. Muscle relaxants should be avoided.

**Teratoma.** A teratoma is a tumor composed of a variety of tissues. The tumor may be so extensive that a tracheostomy may be necessary from the onset. Sedation and muscle relaxants should be avoided. Tumor manipulation can cause airway compromise even with an endotracheal tube in place. Dislocation of the tube by surgical manipulation is also a possibility. Vagal reflexes are very active and severe arrhythmias can occur with laryngoscopy.

**Disorders of the pediatric glottis and larynx**

The airway is narrowest at the larynx, making it a hazardous site for respiratory obstruction, especially in infants. It has been calculated that edema of 1 mm of the mucosal surface of the larynx...
will reduce the glottic cross-sectional area from 14 mm$^2$ to 5 mm$^2$, or by 35-50%.

**Juvenile laryngeal papillomatosis.** Juvenile laryngeal papillomatosis is a viral condition characterized by hoarseness and respiratory distress and the appearance of multiple papillomas on the larynx. The problem usually presents at ages two to four and may be life threatening. The child is repeatedly taken to surgery for laser evacuation of the papillomas. Premedicants should be avoided until the airway is secured.

A laryngoscope, bronchoscope (rigid in case intubation is impossible) and tracheostomy set should be available. A muslin- or foil-wrapped endotracheal tube is necessary for the laser procedure. Induction must be slow because the small laryngeal opening limits gas exchange. Maximum anesthetic levels are required. Visualization is often difficult and may require the use of a bronchoscope. The origin of the laryngeal opening may be determined by applying pressure to the chest to force air outward through the glottis, producing a bubble and indicating the laryngeal opening. Positive pressure ventilation should be avoided because a papilloma may be forced into the airway and act as a “ball valve.”

Because deep levels are required, emergence may be slow. Extubation should be done only when reflexes have been established and the child is fully awake.

**Acute epiglottitis.** Epiglottitis is a life-threatening process involving the supraglottic region. It is most commonly due to the Hemophilus influenza type B organism, although some cases of B hemolytic streptococci have been isolated. The epiglottitis, aryepiglottic folds and arytenoids are involved. The highest incidence occurs during the spring and fall months in preschool children ages three to six. The process usually begins with a sore throat, dysphagia and a thick voice, followed by a high fever, tachycardia, cough, apprehension and a shocky appearance. The disease progresses very rapidly and may be fatal if not treated (Figure 3).

The child classically has to sit forward with his mouth open to breathe, commonly referred to as the tripod position. Inspiration is slow with stridor and retraction. The expiratory phase is unaffected. The child drools from excessive secretions. The airway may completely obstruct within minutes, and the child should never be left alone. With the sitting position maintained, the child should be transferred to the operating room accompanied by an otolaryngologist and an anesthetist. Laryngoscopy should never be attempted outside of the operating room. The preferred method of laryngoscopy and intubation is under general anesthesia without the use of muscle relaxants.

Once clinical stages of anesthesia have been established, an intravenous line should be started. Lidocaine 1-1.5 mg/kg and atropine 0.1 - 0.6 mg should be given prior to intubation. Cyanosis and
obstruction may occur during induction and the incidence of hypoxic bradycardia may be reduced if the vagus is effectively blocked.

Under laryngoscopy the epiglottis appears bright cherry red. Endotracheal intubation should be performed immediately or, if necessary, a tracheostomy should be performed to establish oxygenation. If prolonged intubation is anticipated, a nasotracheal tube may be preferred. Treatment consists of broad spectrum antibiotics. Extubation is performed in two to three days, but never before the child has been afebrile for 24 hours.1

Laryngotraechobronchitis (LTB or croup). Croup is the major cause of acute laryngeal obstruction in children. Croup is a condition resulting from acute and severe obstruction of the larynx due to infection, edema, foreign body or neoplasm. It is characterized by stridor, hoarseness and a barking cough (Figure 4).

Inspiratory stridor, rhonchi, rales and wheezing may be present. Croup often appears at the second year of life and is more common in boys than in girls.

The administration of oxygen is necessary to prevent hypoxemia. Nebulized water and warm humidified air have been helpful and nebulized racemic epinephrine has been extremely valuable in treating this condition. If these measures fail and symptoms worsen, nasotracheal intubation or tracheostomy is necessary. It is estimated that 3% of patients with LTB require an artificial airway.

Bronchiolitis. Bronchiolitis is an acute viral infection caused by para-influenza 3 virus. It is manifested by wide-spread inflammation of the bronchiolar and interstitial cells with edema that obstructs smaller air passages.1 Occurrence is usually at three to four months, is more common in males and is frequently found in infants with an allergic familial history.5

The main characteristic is small airway obstruction with marked increases in expiratory resistance. Air trapping is marked and the work of breathing is three to six times normal.1 Intubation as well as mechanical ventilation are necessary if the PaCO₂ is above 55 Torr.

The bleeding tonsillectomy and adenoidectomy. The bleeding tonsillectomy and adenoidectomy present a high risk induction situation. These children usually swallow significant amounts of blood so not only are they hypovolemic, but they also have full stomachs. The patient should be transported to the operating room in the semi-prone position to facilitate drainage. Induction and intubation should be performed in a full right lateral position with head-down tilt. This permits the bleeding points to be lower than the larynx and also prevents passive drainage into the trachea.8 A high volume tonsil suction should be available. Fortunately, the anesthetist can select the tube size from the previous anesthetic.

Foreign body aspiration. Aspiration of a foreign body is most common from 18 months to four to five years of age. The emergent nature is determined by the location of the aspirant. The foreign body may be lodged in the esophagus, larynx, trachea or bronchi. Esophageal aspiration causes difficulty in swallowing and increases salivation. A rapid sequence induction with Sellick Maneuver is preferred once an intravenous route has been established.

Aspirants are usually easy to retrieve and pose few if any respiratory problems. Foreign bodies aspirated into the respiratory tract usually produce choking, prolonged cough, wheezing and cyanosis. If the foreign body is located in the larynx or trachea, care must be taken not to turn a partial obstruction into a complete one. Retrieval of a tracheobronchial foreign body requires the use of a ventilating bronchoscope following inhalation induction, unless the severity of oxygenation status warrants awake visualization.

Disorders of the pediatric trachea and bronchus

The trachea or bronchus may be narrowed by a substernal thyroid, subglottic hemangioma or mediastinal mass. Vascular rings and infectious processes of the pharynx frequently cause narrowing of the trachea.10

Mediastinal masses. Patients with mediastinal masses require surgery for diagnostic and therapeutic purposes. Large masses can compress or invade the airways, the superior vena cava, pulmonary artery, spinal cord, left recurrent laryngeal nerve, heart or pericardium.11 In children, 44% of the cases are neurogenic appearing as neuroblastomas in the first year of life.11 Benign masses (bronchial cyst, teratoma) commonly involve the airways. Tracheal bronchial compression occurs in 55% of children with newly diagnosed Hodgkins disease; 10% of these children have life threatening airway problems during general anesthesia.12

Preoperative inquiry about the child’s position during sleep may give some indication of impending obstruction. Does the child avoid the supine position? Often turning the child on his side may reduce the severity of the symptoms by displacing
the tumor weight. Tracheal or bronchial obstruction can occur unexpectedly at any time during anesthesia (induction, intubation, positioning, surgery or recovery). Clinically, either a normal airway is present preoperatively which then may become severely obstructed after induction of general anesthesia, or a dramatic airway obstruction is present from the onset.

If compression or severe deviation of the trachea is present, intubation may cause complete obstruction if the tube orifice rests on the tracheal wall. A long thin endotracheal tube or a narrow bronchoscope passed beyond the stenosis may be necessary to provide adequate oxygenation. Awake intubation with fiberoptic bronchoscope is the safest approach; however, general inhalation induction can be utilized.

Children with mediastinal masses who present with respiratory symptoms or tracheal compression are at a risk for total airway obstruction preoperatively. General anesthesia can exacerbate extrinsic airway compression in several ways. The lung volume is reduced due to an increase in abdominal muscle tone and a decrease in inspiratory muscle tone, the result of which is the loss of the tethering effect of expanded lungs on airways. Bronchial smooth muscle relaxation results in a decrease in expiratory flow rate, and paralysis eliminates diaphragmatic movement; both of these conditions will exacerbate extrinsic compression. Cardiac output may be compromised and cardiovascular collapse during general anesthesia can occur. Spontaneous breathing appears to alleviate the problem.

Large tracheal masses with their inherent respiratory risks may necessitate the use of extracorporeal oxygenation. Jet ventilation has been employed for obstructions above the cricoid or inability to pass the tube through the cords.

**Tracheoesophageal (TE) fistula.** Acute airway obstruction is generally not a problem with TE fistula; however, several feedings are usually attempted before a diagnosis is made, and aspiration is common. There is an abnormally high incidence of small cricoid rings in these patients. The patient should be intubated awake. Paralysis of the diaphragm may be necessary for a portion of the procedure to provide best apposition of blind esophageal ends. Positive pressure applied to the trachea for intermittent ventilation should be limited to 20 cm H₂O. Excessive pressures and volumes during the division of the TE fistula should be avoided or the lower lung may be over-distended. During fistula division, each breath must be listened for so as to avoid anoxia. The surgeon may periodically help by occluding the tracheal leak to augment oxygenation. The endotracheal tube is usually left in place until suture lines are healed and the child shows evidence of nonaspirating eating patterns.

**Diaphragmatic hernia.** Diaphragmatic hernia is an incomplete separation of the pleural and abdominal cavities due to developmental failure of the diaphragm. The small intestine, colon, spleen and sometimes left liver lobe migrate through the diaphragm.

The left lung is collapsed, and there is a right mediastinal shift and respiratory acidosis with resultant respiratory failure. Surgical repair consists of reduction of the hernia. As the surgery progresses and the hernia is reduced, lung compliance may increase and symptoms improve. The lungs should be expanded at this point. A hypoplastic lung will not expand with positive pressure and may cause a pneumothorax to occur; this may not appear until the peritoneum is closed. Up to this point, tension pneumothorax can vent through the suture line to the atmosphere but once the incision is closed, this is impossible.

Symptoms of a pneumothorax include decreased compliance, decreased breath sounds, bradycardia, hypotension and cyanosis. The treatment includes reopening the chest and inserting a needle through the diaphragm. A tension pneumothorax may be prevented by use of a chest tube.

**Burns**

Pulmonary injury secondary to smoke inhalation accounts for 50-60% of fire-related deaths annually. Inhalation of noxious substances or carbonaceous materials may damage any level of the airway. Sulfur dioxide and nitrous oxide combined with water form a corrosive acid which causes burns.

If any patient is burned in a closed space or has carbonaceous material on his nares or in his mouth, careful assessment of the airway is mandatory. Heat injury is primarily limited to the upper airway and larynx because the nose and mouth are excellent absorbers of heat. Any suspicion of upper airway damage mandates endotracheal intubation. Any delay may make intubation impossible due to distortion of the airway. The problems to be anticipated are those similar to acute epiglottitis, and thus spontaneous breathing is required at all times. Muscle relaxants are contraindicated. If a child is too combative, ketamine may be given.
The adult population

Acute epiglottitis does occur in the adult patient. Because of its larger size and more rigid structure, the adult larynx can sustain inflammatory processes without producing symptoms and signs of airway obstruction. The adult patient with epiglottitis frequently seeks treatment after the inflammatory process has peaked, but on occasion the infection may be severe enough to produce fever, drooling and airway obstruction. Management of these patients includes early detection, laryngoscopy with intubation or tracheostomy if necessary.

Adult patients frequently present with dental or pharyngeal abscesses that limit jaw motion and prevent insertion of the laryngoscope. Acute mandibular cellulitis may distort the facial anatomy and drastically reduce jaw motion.

Tumors of the glottis and larynx

Laryngeal tumors often cause tracheal displacement in addition to obstruction of the glottic area. Large friable tumors may readily slough and bleed. Radiation produces scarring which exaggerates the degree of respiratory compromise. If intubation is expected to be extremely difficult or impossible, prophylactic tracheostomy should be performed. Laryngeal papillomatosis also occurs in the adult population and can produce acute episodes of respiratory distress.

There are several conditions that can cause tracheal deviation in the adult. A few of these are: large thyroid mass, mediastinal mass, thoracic aneurysm and aortic arch aneurysm. A review of the chest x-ray can be helpful in determining the position of the trachea.

Endocrine and allergic disorders

Nutritional disorders such as pickwickian syndrome, with its massive obesity, are often associated with sleep apnea. Tracheostomy is sufficiently difficult in the obese patient to warrent prior endotracheal intubation. The use of pre-operative sedatives is an absolute contraindication. Acromegalic patients commonly have a reduced cricoid ring diameter requiring a smaller than normal endotracheal tube.

Acute allergic response to medications may precipitate laryngeal edema or acute macroglossia, complicating laryngoscopy and intubation. Individuals with environmental allergies are prone to laryngospasm or bronchospasm.

Trauma

 Crushed larynx. The incidence of crushing injury to the upper respiratory tract has been decreased by the use of seat belts, but paradoxically this has resulted in a greater number of survivors with laryngotracheal injury.16 Laryngeal trauma is the second most common cause of death associated with maxillofacial trauma. Even though the larynx is fairly well protected, the inertial forces of impact cause the neck to hyperextend, exposing the laryngeal structures and fixing them upon the cervical vertebra posteriorly.16

On impact, the larynx is crushed between the dashboard anteriorly and the cervical spine posteriorly, resulting in any one or a combination of findings: (1) midline or paramedial fracture of the thyroid cartilage; (2) pulverized thyroid notch; (3) separation of the thyroarytenoideus muscle, producing tears in the vocal cords; (4) pyriform, upper cervical esophagus and pharyngeal lacerations; (5) interstitial hemorrhage; and (6) fractures of the cricoid or hyoid bone with or without evulsion of the epiglottis.16

Signs and symptoms of laryngeal laceration include aphonia due to dislocation or hematoma of the arytenoid or vocal cord, persistent neck pain, hemoptysis, dyspnea, subcutaneous emphysema, mediastinal emphysema and tension pneumothorax.

Treatment includes a low tracheostomy to relieve the emphysema and airway obstruction. Open reduction with splinting is secondary to establishment of adequate oxygenation.

Lacerated trachea. Frequently a diagnosis of lacerated trachea is not made until the patient has been anesthetized and paralyzed. Paralysis may separate the free ends of the trachea making intubation impossible. Inability to advance an endotracheal tube with associated trauma to the neck or chest should alert the anesthetist to the possibility of tracheal laceration. Emergency tracheostomy is life saving.

Facial trauma. Other types of trauma include severe lacerations and fractures of the facial bones, gunshot wounds to the face, and explosive trauma to the face. The method of airway control depends largely on the degree of airway compromise and the anatomical availability of respiratory orifices.

Frequently, management is complicated by the presence of blood, teeth and bone fragments in the oral cavity and airways. In a patient with severe fractures of the nasoethmoid complex, nasal intubation should be avoided if possible, both to avoid contributing to the infection of cerebrospinal fluid and to avoid inadvertently passing a tube through the cranium.8
The major hazard of the use of an endotracheal tube is the risk of carrying foreign bodies into the airway during intubation.

Summary

Lack of knowledge and/or an inadequately prepared anesthetizing arena can lead to devastating results if the anesthetist is faced with any one of the aforementioned problems. Careful assessment of the degree of respiratory embarrassment present or of the potential problems that can be encountered with the induction of general anesthesia is paramount in order to avoid life threatening consequences.

REFERENCES

AUTHOR
Cathy Mastropietro, CRNA, MEd, is a graduate of St. Elizabeth Hospital School for Nurse Anesthetists, Youngstown, Ohio. She earned an MEd from Youngstown State University in Youngstown. Ms. Mastropietro is currently the director of the School for Nurse Anesthetists, St. Elizabeth Hospital Medical Center, Youngstown.