Lesson 242: PreAnesthetic Assessment of the Pediatric Patient With a Difficult Airway

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Dr. Kaye has disclosed that he is a member of the speakers' bureaus of Pfizer and Baxter and has received grant/research support from SkyePharma and Baxter. The other authors have no relationships with pharmaceutical companies or products to disclose. This educational activity may contain discussion of published and/or investigational uses of agents for the treatment of disease. Some uses of these agents have not been approved by the US Food and Drug Administration. Please refer to the official prescribing information for each product for approved indications, contraindications, and warnings.

Lesson 242 was reviewed by Irene Osborn, MD, Associate Professor, Department of Anesthesiology, Mount Sinai School of Medicine, New York, NY. Dr. Osborn has disclosed that she has been a consultant and lecturer for LMA North America.

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LEARNING OBJECTIVES

At the end of this activity, the participant should be able to:

1. Summarize the special anesthetic problems presented by the pediatric patient with a difficult airway.
2. Describe the systemic changes and symptoms associated with the difficult pediatric airway.
3. Apply appropriate preoperative testing and evaluation in the management of these patients.
4. Outline the anatomic differences between the airways of adults and children.
5. List the equipment used to manage a difficult pediatric airway.
6. Identify the variant presentations of a difficult airway.
7. Present an anesthetic and analgesic plan for the treatment of these patients.
8. List associated complications in the management of the difficult pediatric airway.
9. Cite the incidence of various airway conditions.
10. Anticipate, recognize, and manage likely perioperative complications in pediatric patients with a difficult airway.

CASE HISTORY

A 4-year-old boy weighing 18 kg was brought into the emergency department with an incarcerated hernia. Preoperative assessment revealed mild inspiratory stridor and a cough described as a seal bark. The parents stated that the cough had begun 2 days before admission and had worsened at night. The boy had a temperature of 100.4°F; his vital signs were within normal limits. A physical examination revealed nasal flaring, occasional expiratory wheezing, and suprasternal retractions. A chest X-ray indicated no bony abnormalities, effusions, or infiltrates.

NEEDS STATEMENT

A failed airway can result in a catastrophic event including hypoxia, brain damage, myocardial infarction, and death. The pediatric population, in particular, may present for treatment with extraordinary complications that make airway management difficult. The appropriate means to deal with difficult airway situations in children has been identified by reader responses and by committee as required knowledge for the practicing anesthesiologist.

When managing the airway of a pediatric patient, an anesthesiologist must have more than a practical familiarity with the anatomic differences between the airways of adults and children. It is crucial that the clinician take a proper medical history and perform a physical examination before selecting equipment for intubation. The clinician must also evaluate the patient for any potential congenital syndromes that can complicate an intubation. Securing the difficult airway requires cooperation and planning with pediatricians, otolaryngologists, and pulmonologists. Guided by professional judgment and the preoperative examination findings, the anesthesiologist should be able to foresee and prevent complications during perianesthetic management. In all instances, a difficult airway cart should be available with equipment that is sized for the child (Table 1). The contents of this cart should be prepared and frequently reviewed by the anesthesiologist.

Anatomic Differences in the Airways Of Adults and Children

The anesthetic management of children is different from that of adults because of anatomic differences in their airways. Knowledge of these differences may prove critical for management of the difficult pediatric airway.

The infant's tongue is much larger relative to the oral cavity than that of the adult, which may lead to a higher risk for airway obstruction—especially in the neonate. The infant's larynx also differs anatomically from that of the adult. The infant's larynx is higher in the neck than an adult's (C3-4 level instead of C4-5) and thus is harder to visualize; the view of the larynx is blocked more by the proportionately larger tongue. To accommodate this difference in anatomy, a straight laryngoscope blade is typically the better choice. The relationship between larynx and tongue is further distorted by diseases associated with mandibular hypoplasia—for example, Pierre Robin syndrome.

Compared with that of an adult, the child's epiglottis is much narrower and angled away from the trachea, a variation that can challenge the physician attempting to lift the epiglottis with a laryngoscope blade. Furthermore, the attachments of the vocal folds are lower and more anterior in the child than in the adult, which can lead to occasional problems, especially when a nasotracheal approach is indicated.

More differences can be seen when the subglottis of a child is compared with that of an adult. The subglottis is the narrowest portion of the child's larynx, whereas the rima glottidis is the narrowest area in the adult. Although this difference may seem trivial, it becomes critical should the endotracheal tube not pass the subglottis. Positioning the endotracheal tube in the vicinity of the subglottis may cause edema, a problem that increases resistance in the pediatric airway during extubation.[1]

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PREANESTHETIC ASSESSMENT

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Table 1. Airway Equipment for the Difficult Airway Cart

- Laryngoscope blades and handles (spares)
- Nasal and oral airways
- Endotracheal tubes
- Stylets and endotracheal tube guides
- Fiber-optic intubation equipment
- Retrograde intubation equipment
- Supraglottic ventilatory devices
- Dilational percutaneous cricothyrotomy kits
- Jet ventilation stylets
- Equipment for jet ventilation
- Endotracheal tube exchangers
- Exhaled CO_2 detector

Table 2. Congenital Abnormalities and the Pediatric Airway

Site of Abnormality	Clinical Condition/Presentation
Nasopharynx	Choanal atresia, stenosis, encephalocele
Tongue	Hemangioma, Beckwith-Wiedemann syndrome, Down syndrome
Mandible/maxilla	Pierre Robin syndrome, Treacher Collins syndrome, Turner syndrome, achondroplasia
Pharynx/larynx	Laryngomalacia (infantile larynx), Freeman-Sheldon syndrome (whistling face), laryngeal stenosis, laryngocele, laryngeal web
Trachea	Vascular ring, tracheal stenosis, tracheomalacia

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Eckel and colleagues[2] analyzed the morphologic changes of the larynx during the early developmental years in 43 children aged 1 to 60 months. The subglottic airway increased in size during the first 2 years of life, from 13 to 28 mm on average. Afterward, this area showed more linear growth. Thus, the child's larynx is not simply a smaller version of the adult organ, and postnatal maturation of approximately 5 years must occur before significant similarities appear.[2]

The differences between the adult and pediatric anatomy can cause other problems. The larynx, trachea, and bronchi are more compliant in the infant than in the adult, so that they are vulnerable to distending and constricting forces. For example, the child's airway may close during bronchial smooth-muscle contractions in disease states such as reactive airway closure. The greater compliance of the pediatric airway can endanger preterm and term infants during quiet respirations. The difficult pediatric airway is especially at risk if the child is struggling. Should the child cry during induction, the transluminal pressure may increase dramatically and cause dynamic airway collapse. To prevent this problem, parents, nurses, and physicians should try to keep the child calm, especially during induction. Premedication should be used as appropriate.

Differences in muscle physiology can also lead to problems in infants if the airway becomes compromised. Infants have fewer type I muscle fibers in the diaphragm and intercostal muscles than do adults. Small babies tire more quickly during respiratory work and are at greater risk for respiratory failure.[1]

Airways vary considerably among children, requiring flexible equipment, a wide range of tube sizes and techniques, including fiber-optic bronchoscopy, and the use of child-sized supraglottic ventilatory devices and small lighted stylets (light wands).[3] New devices created in the hope of improving management of the difficult airway include a child-sized video-assisted laryngoscope, recently available on the market. Studies are also being conducted to determine if the laryngeal mask can be used to improve the guidance of fiber-optic intubation.[4]

Medical History and Airway Evaluation

The anesthesiologist should evaluate a child especially carefully if risks for a difficult airway or obstruction during surgery are identified—such as respiratory infections, congenital abnormalities, laryngeal papillomas, and aspirated foreign bodies. Accounts of recent or past upper respiratory tract infections are important.[1] Most upper respiratory tract infections are related to the common cold, acute otitis media, sore throat, or bronchitis. Other major factors that may predispose to upper respiratory tract infections include a positive family history of frequent upper respiratory tract infections, asthma, and allergies (which may be associated with nasal polyps).[5] The physician should also inquire about tonsillitis and the current use of antibiotics, antihistamines, or any other medications, including over-the-counter drugs (especially those that may contain aspirin or related compounds). Aspirin and nonsteroidal compounds are found in many nonprescription cold medicines and in antihistamine preparations; this information is vital to the preoperative evaluation because such drugs can interfere with platelet function and increase the risk for bleeding.[6]

Risk factors for a difficult pediatric airway include audible respiration, chest retractions, mouth breathing, and nasal congestion. A history of snoring or discomfort during sleep may also be considered a risk factor. The aforementioned symptoms all point to tonsillar/adenoid hypertrophy, obstructive sleep apnea (OSA), or an upper airway obstruction secondary to congenital abnormalities or foreign bodies that may jeopardize the airway during surgery.[1,6,7] Studies have shown that such symptoms may predict postoperative complications, such as airway obstruction and problems with future intubation, so that these patients are candidates for extended inpatient observation.[8] Previously, it was thought that OSA increased the risk for acute upper airway obstruction if sedatives were used. However, a study of 65 children demonstrated that the use of oral midazolam hydrochloride before surgery does not have any significant adverse effects. Hence, preoperative sedation may be administered to children who have OSA—possibly even severe cases. Nevertheless, it would seem reasonable to closely observe such higher-risk patients perioperatively.[9] Unfortunately, because reports of techniques and outcomes rarely undergo comprehensive examination, the area of pediatric sedation remains controversial and requires further studies, especially with regard to the parenteral administration of benzodiazepines.[10]

Pulse oximetry is a good screening tool for OSA, which is diagnosed if the oxygen saturation is less than 90%.[6] In children with chronic OSA, formal sleep studies with polysomnography may be warranted; such studies are the best means to assess the severity of OSA. Another helpful tool for locating upper airway obstruction is sleep nasendoscopy. For the anesthesiologist to perform this procedure, the pediatric patient must be deeply anesthetized (with sevoflurane and oxygen administered via a mask); the nasendoscope is then introduced through the nostrils. Once the nasendoscope reaches the postnasal space, the anesthesiologist can manipulate the airway to induce an obstruction so that the surgeon can visualize the site of airway obstruction with the camera.[11] Microlaryngobronchoscopy can be used to examine a child with daytime noisy breathing, a history of cardiac malformations, or Down syndrome and may assist the team in ruling out a more distal site of airway obstruction.[12]

Another risk factor for a difficult pediatric airway is episodes of coughing. A physician who examines a coughing child with a respiratory tract infection should determine if the cough is similar to a "seal bark." This abnormal coughing sound signifies laryngotracheobronchitis (croup) secondary to viral infection and may predict respiratory problems after extubation.[6,13]

In a child with one or more of the aforementioned risks—such as upper respiratory tract infection or tonsillitis—inflammation from these conditions can extend into the lower respiratory tract. The result can be edema and bronchospasm,[6] mainly secondary to the release of proinflammatory cytokines and mediators from airway epithelial cells. The cytokines act on the microvascular endothelial cells to produce alveolar edema. Neural changes of airway tone can cause bronchospasm due to enhanced parasympathetic efferent neuronal activity, the release and activation of bronchoactive neuropeptides from sensory C fibers in the airways, or modulation of the noradrenergic system.[14] Wheezing, rales, and stridor on chest auscultation are strong indicators of airway obstruction from bronchospasm or tonsillar/adenoid hypertrophy.[6] Children with stridor have partially obstructed airways, and the physician should auscultate carefully.[15]

Although it is rare, psychogenic stridor—more common in girls—can cause an acute upper airway reaction.[16] This type of complication may present as asthma, stridor, or epiglottitis and is unresponsive to conventional treatment. Usually, no organic pathologic processes are found, and psychosocial stressors are present. In a study of 48 cases, 52% were given a diagnosis of conversion disorder.[11] In some such cases, the airway obstruction can be severe enough that the patient requires general anesthesia, intubation, or even tracheostomy.[17,18] If such a case arises, the team should perform a fiber-optic nasendoscopic examination of the larynx to look for an abnormality on adduction of the vocal cords during inspiration—the most likely cause of this type of stridor. A positive diagnosis indicates the need to consult an otolaryngologist and/or a pulmonologist.[16]

The quality of the child's speech must also be considered. A gravelly voice may indicate a laryngeal papilloma—a condition in which normal sounds progress to hoarseness, aphonia, and finally respiratory distress. Identifying abnormalities such as laryngomalacia and vocal cord paralysis is also important during the evaluation.[19]

The anesthesiologist should be attentive to children with craniofacial syndromes or anatomic malformations. Congenital syndromes that can cause airway obstruction should be noted, including Pierre Robin, Treacher Collins, Goldenhar's, Apert's, Turner's, and Crouzon syndromes, in addition to many others.[1] Furthermore, the anesthesiologist should examine the shape of the patient's jaw to determine if any previous reconstructive surgery has been performed. A highly arched or narrow palate may be a sign of chronic nasopharyngeal obstruction.[6,7] Finally, the anesthesiologist should note the size of the mandible; if it is disproportionately small, it can lead to intubation difficulties. The naturally small mandibles of young children are even smaller in those with Pierre Robin, Treacher Collins, Goldenhar's, or other micrognathic syndromes.[13]

An important part of the patient's medical evaluation is measurement of the distance between the hyoid bone and the mandible. The normal anterior–posterior distance from inside the mentum of the mandible to the hyoid bone is 1.5 cm in infants—contrasted with 3 cm in adults. If the measure-

ment is less than 1.5 cm, the physician can predict a complicated intubation.[3] Other physical aspects of the patient that should be taken into account are the facial expression, presence of nasal flaring, color of the mucous membranes, and respiratory rate. Also, the physician should be aware of any loose or missing teeth and the location of the larynx.

The baseline oxygen saturation in room air is useful for assessing the need for prolonged, frequent bronchodilator therapy in children with acute asthma. For example, if the oxygen saturation is 91%, the child may need frequent bronchodilator therapy for more than 4 hours. If the oxygen saturation is 89% or lower, the child with asthma may need frequent bronchodilator therapy for more than 12 hours. Such information can be useful for predicting whether a pediatric patient has a potentially difficult airway.[20] Other conditions may also be associated with relative hypoxia.

Conditions such as recent pneumonia, bronchitis, upper respiratory infection, chronic sleep apnea, and cor pulmonale indicate the need for chest radiography and electrocardiography (ECG) as part of the evaluation.[6] For example, in children with pneumonia, the T wave of the ECG is depressed and actually rises as the child starts to recover. The ECG is also useful for detecting myocarditis secondary to pneumonia in infants.[21]

Another example of the benefits of these diagnostic tests can be seen in the patient with chronic sleep apnea. The radiographs of such patients can show enlargement of the tonsils and adenoids. In addition to these findings, the ECG can detect abnormalities of the heart, such as right ventricular hypertrophy.[22] Chronic airway obstruction or compensated respiratory acidosis may indicate the need for blood gas analysis; however, needle puncture is contraindicated if it upsets the child and further compromises the airway.

Any history of foreign body aspiration, causing increased airway reactivity, obstruction, or impaired neurologic function, should be determined. The anesthesiologist should also determine whether any previous anesthetic problems related to the airway have caused complications with intubation, extubation, or mask ventilation. It may be necessary to access previous records because incidents of desaturation may not have been communicated to the parents, especially if the outcome was favorable.

Allergies may also compromise the airway as a result of increased reactivity. The airways of asthmatic patients can become hyperreactive when exposed to dust mites, allergens from household pets (eg, cats and dogs), or other particles that can induce the abnormal synthesis of IgE in local airways.[1,23,24]

A good medical history can help the anesthesia provider to anticipate a challenging intubation and better prepare for a potentially difficult pediatric airway.

Congenital Abnormalities

The anesthesiologist must be aware of congenital abnormalities that can potentially cause a difficult airway situation (Table 2). Most pediatric airway difficulties are not the result of an abnormal larynx or trachea; rather, the difficulty lies in accessing the airway. Micrognathia, a condition in which the jaw is hypoplastic, makes it difficult for the physician to use a laryngoscope because the space in which to maneuver is small (as a result of displacement of the area by soft tissue). This problem is seen in certain congenital disorders, including the following syndromes: Pierre Robin, Treacher Collins, and Goldenhar's (hemifacial microsomia). In patients with congenital abnormalities like Pierre Robin syndrome, an excellent choice for managing the difficult airway is the light wand, a rigid stylet with a light on its tip that the anesthesiologist can use to visualize the neck. In infants, however, too much light from a light wand can make it difficult to distinguish between esophageal and tracheal intubation. This challenge can be addressed by using light wands that have external light sources with rheostatic control. These devices allow a physician to manipulate the light to accommodate an infant's airway with a 2.5-mm light wand.[3]

When treating a pediatric patient who has a difficult airway, the anesthesia provider must sometimes induce anesthesia because children can be uncooperative in many situations.

Table 3. Endotracheal Tube Sizing for Patients With Down Syndrome[27]

Age	Size (DS), mm	Size (Normal), mm
>14 y	6.5	7.5-8.0
12-13 y	6	7.0-7.5
10-11 y	5.5	6.5-7.0
8-10 y	5.5	6.0-6.5
6-7 y	5	5.5-6.0
4-5 y	4.0-4.5	5.0-5.5
1.5-3 y	3.5-4.0	4.5-5.0
9-18 mo	3.0-3.5	4.0-4.5
Full-term to 9 mo	2.5-3.0	3.5-4.0
Premature	2.0-2.5	2.5-3.0

DS, Down syndrome

However, the breathing sounds—a valuable guide for locating the glottis—may be depressed in a patient under anesthesia. In these situations, the anesthesiologist may have a more difficult time if the patient has a congenital syndrome, such as Pierre Robin or Treacher Collins syndrome, in which the epiglottis can be seen only with rigid laryngoscopy. This obstacle can be overcome by shaping the endotracheal tube into a 90-degree angle with the stylet and placing the tip behind the epiglottis. The anesthesia provider can then hear breathing sounds by placing an ear to the proximal trachea. This procedure allows the glottic opening and trachea to be located, even in the inherently difficult situation of anesthesia in a patient with a congenital syndrome. Supraglottic ventilatory devices have been successfully placed in awake patients with Pierre Robin syndrome. A child-sized indirect rigid fiberoptic laryngoscope for direct visualization of the laryngeal inlet is also useful for securing the airway in patients with congenital defects (eg, those seen in Pierre Robin, Treacher Collins, and Goldenhar's syndromes) because it allows the physician to better visualize the larynx.

Children with Down syndrome, the most common congenital chromosomal anomaly, may also present with airway problems. In addition to mental retardation, these patients can have multiple ear, nose, and throat malformations, including midface hypoplasia, abnormal dentition, macroglossia, a shortened palate, and a narrowed nasopharynx and oropharynx.[25,26] One of the most important anesthesia-related considerations for this patient population is the choice of an appropriately sized endotracheal tube. Generally, the diameter of the tracheal lumen in children with Down syndrome is decreased. Age is now recognized as the most reliable indicator of the appropriate endotracheal tube size; children with Down syndrome require endotracheal tubes at least 2 sizes smaller than would normally be anticipated to avoid airway trauma (Table 3).[27]

Patients with Down syndrome are at increased risk for atlantoaxial instability and subluxation. Therefore, they should undergo a preoperative neurologic assessment and radiography in the lateral, extension, and flexion positions when warranted. Any abnormalities should be investigated before surgery. A survey study revealed that for symptomatic patients, a majority of anesthesiologists obtained radiographs (64% of the time) or consultations (74%). Furthermore, approximately half of the survey respondents maintained a neutral position of the head and neck for patients with Down syndrome, regardless of the presenting symptoms.[28,29] A recent case report suggested that neuraxial anesthesia or use of a laryngeal mask airway may be appropriate in certain patients with Down syndrome. These techniques may help avoid the possible complications of a tracheal intubation.[30]

Patients with mucopolysaccharidoses, such as Hurler's syndrome and Hunter's syndrome, can exhibit atypical airways. These diseases are characterized by a deficiency of the enzymes responsible for the catabolism of glycosaminoglycans. Patients may present with mental retardation, joint immobility, and vision or hearing loss. Laryngeal and tracheal irregularities may present extreme anesthetic challenges when intubation is attempted. Computed tomography in these patients has revealed abnormal shapes of the vocal cords and trachea, and a smaller tracheal surface area than that of other individuals. Although the cause of the irregularities is unknown, the abnormal submucosal storage of keratin or dermatan sulfate may play an underlying role in the pathology of the disorders.[31] Patients should be thoroughly evaluated preoperatively through clinical and laboratory investigations. Lung function in particular should be optimized with the treatment of airway infections and lung physiotherapy.[32]

Externally, these pediatric patients may appear to have normal facies; only with laryngoscopy is the actual difficulty realized. Significant epiglottic and glottic narrowing may require fiber-optic intubation or the use of a laryngeal mask airway in this population. Because airway anomalies, bleeding, and salivation can complicate intubation, spontaneous respiration by the patient is recommended with the use of general anesthesia, until the trachea has been intubated. Local or regional anesthesia is favored, although in some cases this may be contraindicated by the age and mental status of the patient.[32,33] Even with the use of smaller tubes, extubation may prove to be difficult. The narrowing of the trachea may be aggravated by intubation itself, and it may become necessary to urgently replace the tracheal tube if the patient's airway cannot be maintained. In such cases, conventional equipment, emergency cricothyroid puncture, and tracheostomy may not be viable options. Often, it is difficult to palpate the upper trachea because of an extremely short and stiff neck; therefore, the anesthesiologist must be prepared to reintubate the patient with a fiber-optic scope, if necessary.

Following reintubation, individual circumstances dictate if a surgical tracheostomy is warranted. Not only is this a difficult procedure; also, long-term problems, such as tracheal stenosis, can develop. Consequently, tracheostomy should not be performed unless it is absolutely necessary. Postoperatively, the combination of lung physiotherapy with positive end-expiratory pressure, along with antibiotics, helps to treat stagnation of secretions and airway infections. Currently, there is no ideal solution to the problems described. Hence, these patients should be managed in a specialist center if possible.[32,33]

Intravenous atropine 0.02 mg/kg or glycopyrrolate 0.05 mg/kg should be prepared for all cases of congenital anomalies. These drugs are excellent drying agents for excessive secretions that can further hamper the difficult airway—a problem that is exacerbated by multiple attempts at intubation. Airway obstruction occurs quickly, and therefore the emergency airway device, surgical supplies, and appropriate personnel should be in the operating room before the induction of anesthesia.[3]

The fiber-optic bronchoscope is useful in many cases when congenital abnormalities preclude the use of conventional equipment. Intubation with this tool is facilitated by its flexibility in abnormal airways. The limited field of vision that it provides can be rendered useless if bleeding or secretions are present. Another disadvantage is that the fiberoptic bundle is fragile and expensive; furthermore, an experienced user is required.[1]

Infections

Epiglottitis

Infections occur often in difficult airways. Acute epiglottitis, which can result from infection by *Haemophilus influenzae* type B, is a significant threat for children. This infection has been known to progress rapidly from a sore throat to airway obstruction. To make matters worse, the obstructed airway can result in respiratory failure and death within a short time if the physician does not diagnose the condition promptly and successfully intervene. Children aged between 2 and 7 years are at greatest risk for epiglottitis. It is recommended that children be vaccinated against this infection before the age of 2 years.

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Table 4. Infections in Pediatric Patients With Difficult Airways[1]

Infection	Pathogens	Description
Acute epiglottitis	*Haemophilus influenzae* type B	Cellulitis of the supraglottic structures causes airway collapse. Involvement of the posterior lingual surface and surrounding soft tissues, in addition to the epiglottis and aryepiglottic folds. Infection can result after collapse of the airway.
Bacterial laryngotracheo-bronchitis (croup)	Primarily *Staphylococcus aureus*; *H. influenzae*, α-hemolytic streptococci, and *Streptococcus pneumoniae* are also causes.	Subglottic edema with ulcerations; pseudomembrane formation in the trachea; positive bacterial cultures.
Upper respiratory infection	Various	Reactive airway, bronchospasm, laryngospasm.
Laryngotracheal (subglottic) stenosis	Prolonged use of endotracheal intubation can make the airway vulnerable to infections.	Edema, necrosis, mucosal ulcerations, and infections can develop secondary to exposure of the cartilage.

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Characteristics of epiglottitis include the sudden onset of fever, dysphagia, drooling, and a thick, "muffled" voice. The affected child prefers to sit with his or her head extended and thrust forward. The infection is essentially a cellulitis of the supraglottic structures. The posterior lingual surface and surrounding soft tissues, along with the epiglottis and aryepiglottic folds, are primarily involved. Airway collapse is likely as a result of the infection. The anesthesiologist should try to calm the child because crying and agitation can make matters worse. In addition, the healthcare team should avoid blood drawing, sedation, I.V. insertion, and excessive handling of the patient because these activities can provoke further emotional distress.

In the early stages of an obstruction, the child looks pale and "toxic"; these symptoms progress to labored breathing, cyanosis, and retractions. The diagnosis can usually be made on the basis of clinical suspicion; however, in some cases, radiography may be useful to confirm the diagnosis and rule out conditions such as croup, retropharyngeal abscess, and foreign body aspiration. Characteristic findings include a round and thickened epiglottis (thumb sign), loss of vallecular air, and thickening of the aryepiglottic folds. These findings are best determined by a lateral neck X-ray obtained with hyperextension during inspiration. These findings should then be confirmed with direct visualization of the pharynx and larynx—ideally in the operating room.[34]

The patient with epiglottitis should be handled expeditiously. The child should be rushed from the emergency room to the operating room with surgeon and anesthesiologist in attendance. The parents should be present only if they can help to calm the child. Endotracheal intubation is usually the best choice to establish the airway. The physician should use a pulse oximeter and precordial stethoscope while other monitors are placed on the child sitting in the operating room. Preparations should include the availability of equipment and personnel for laryngoscopy, rigid bronchoscopy, and tracheostomy. Anesthesia is usually induced with a combination of 100% oxygen and increasing concentrations of sevoflurane, which can be used as a single-breath technique.

The sedated child should be placed in the supine position. The anesthesiologist should perform laryngoscopy and endotracheal intubation without the use of muscle relaxants. It is wise to work with an endotracheal tube at least 1 size (0.5 mm) smaller than might be expected. A helpful supplement to the procedure is a lighted stylet.[35] This malleable stylet, equipped with a high-intensity light at the tip, is useful to achieve proper positioning, thus facilitating advancement of the endotracheal tube. The tool is employed in situations in which there is no intrinsic pathology but visualization of the airway is difficult.[1] A method of assessing the appropriateness of tube size involves the detection of an air leak. When an air leak at 20 to 25 cm H_2O is detected, one can be confident that the tube is of the appropriate size. In this situation, a larger tube is unnecessary and may lead to subglottic stenosis. Furthermore, the patient should be able to breathe both through and around the tube.[35]

In certain complicated cases, a light wand may be needed for nasotracheal intubation.[36,37] A study in Japan used the light wand method in 46 patients scheduled for nasal intubation. An endotracheal tube was mounted on a light wand with a stiff stylet in position to form an angle of 40 to 60 degrees—about 7 cm proximal to the tip of the endotracheal tube. The procedure resulted in an 89% success rate.[37] Thus, light wand–guided nasotracheal intubation with a stiff stylet in position is useful and can be carried out without traumatic complications. After the nasotracheal tube has been secured, antibiotic treatment can be started as soon as tissue and blood cultures have been obtained. Sedation is recommended for 48 to 72 hours while the patient is under supervision in the intensive care unit. Afterward, extubation is performed once the swelling has subsided—traditionally ascertained with flexible fiber-optic bronchoscopy.[6]

Croup

Laryngotracheobronchitis, also known as croup, is a common infection; it usually occurs in children younger than 3 years but may affect those up to 6 years of age. Croup is the most common infectious cause of upper airway obstruction, with an annual incidence of 18 per 1,000 children.[34] Because the cause of croup is usually viral infection, its onset is more subtle than that of bacterial epiglottitis. The most common pathogen implicated in croup is parainfluenza virus type 1; however, parainfluenza viruses types 2 and 3, influenza viruses A and B, respiratory syncytial virus, and certain adenoviruses are also causative.[38]

The presenting symptoms of croup are low-grade fever, inspiratory stridor, and coughing that sounds like a seal bark. More ominous indications of an impending respiratory collapse include tachypnea, intercostal and suprasternal retractions, nasal flaring, grunting, and biphasic stridor. Radiography can confirm narrowing of the airway column and the "steeple" sign caused by soft-tissue edema. It should be noted, however, that up to 50% of children with croup have completely normal findings on chest X-ray.[34]

Treatment includes the inhalation of cool, humidified mist or oxygen therapy. In certain severe cases with tachypnea, tachycardia, and cyanosis, the use of nebulized or I.V. racemic epinephrine is indicated. Rapid improvement of the patient's condition is seen after the administration of racemic epinephrine, and some studies have indicated that this therapy may decrease the need for intubation.[39] It should be noted, however, that there is some controversy with respect to the effectiveness of this intervention. Some clinicians prefer to give racemic epinephrine only to hospitalized patients for fear of a rebound effect, whereas others are convinced that treated patients can be safely discharged home. There are studies in support of both approaches, and more studies are needed to clarify the issue.[40]

In addition to epinephrine, nebulized or I.V. dexamethasone has been used in the treatment of croup—especially to reduce stridor.[1,6] Treatments such as corticosteroids and helium/oxygen mixtures have also been effective.[41] If the croup becomes problematic because of secretions obstructing the airway, therapy as for epiglottitis may be necessary.[6] Approximately 2% of children hospitalized with croup ultimately require endotracheal intubation and mechanical ventilation. Studies indicate that this number is diminishing with the increasing use of glucocorticoids. When children do require intubation, extubation can generally be accomplished within 2 to 3 days.[34]

Bacterial Tracheitis

Bacterial laryngotracheobronchitis, also known as pseudomembranous croup or bacterial tracheitis, is an emergent infection that causes upper airway obstruction. It is notably rarer than either croup or epiglottitis but can mimic both. Bacterial tracheitis occurs most frequently in the fall and winter months in children between the ages of 6 months and 8 years. It is characterized by the presence of significant subglottic edema—most often the result of infection with *Staphylococcus aureus*, although *Haemophilus influenzae*, α-hemolytic streptococci, and *Streptococcus pneumoniae* have also been implicated.

Clinically, children present with 3- to 7-day prodromal symptoms of a viral upper respiratory infection, including cough and low-grade fever. Their condition then deteriorates acutely (over a period of hours), as tachypnea, high fever, a "toxic" appearance, stridor, retractions, and thick mucopurulent secretions develop. It should be noted that patients with bacterial tracheitis tend not to drool, and they often can lie flat without difficulty.

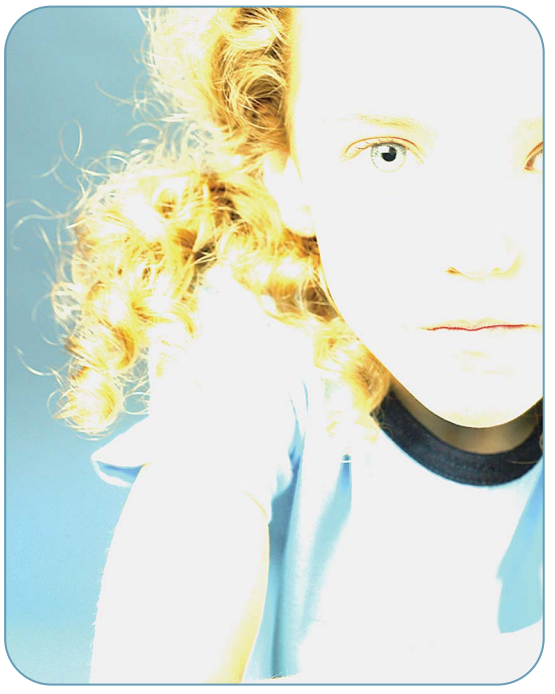
A lateral neck X-ray may not be helpful in differentiating bacterial tracheitis from laryngotracheobronchitis because both can show the characteristic "steeple" sign; however, in bacterial tracheitis, a pseudomembrane detachment is often observed, evidenced by multiple intraluminal irregularities and a hazy tracheal air column. The main clinical features for distinguishing laryngotracheobronchitis from bacterial tracheitis are a more toxic appearance and the lack of a response to racemic epinephrine and glucocorticoids. The diagnosis of bacterial tracheitis can then be confirmed in the operating room by the endoscopic findings of subglottic edema with ulcerations, pseudomembrane formation in the trachea, and positive bacterial cultures.[34] Treatment entails the use of broad-spectrum antibiotics, along with intubation, which is performed in more than 80% of children with bacterial tracheitis.[38] The same considerations for the intubation of patients with

laryngotracheobronchitis also apply in these cases. Intubation is often required for 3 to 7 days, until an audible air leak is detected around the tube, secretions are reduced, and clinical signs of improvement are noted.[34]

Upper Respiratory Infection

Retrospective and prospective studies have documented that a recent upper respiratory infection is commonly associated with the development of adverse respiratory events during intubation—including bronchospasm, laryngospasm, and hemoglobin desaturation.[42] Upper respiratory infections are also problematic because they are quite prevalent (children have an average of 6 per year), and the symptoms can last up to 6 weeks.[43] Thus, the probability is quite high of encountering a pediatric patient with this affliction. In patients with an upper respiratory infection (ie, those with a reactive airway), a laryngeal airway device may be more suitable than intubation. However, the physician should be cautious with the use of these ventilatory devices because the risk for laryngospasm still exists—although in recent studies, a laryngeal mask airway significantly decreased the incidence of all respiratory complications in comparison with endotracheal intubation.[44] It should also be noted that laryngeal airway devices are supraglottic tools, and the pediatric patient is not protected from pulmonary aspiration of the gastric contents.[1]

A more controversial management option for patients with upper respiratory infections who require anesthesia is the administration of bronchodilators before surgery. Pretreatment with bronchodilators has not been shown to decrease the frequency of adverse respiratory effects in patients with recent upper respiratory infections who require general anesthesia.[43]



Laryngotracheal (Subglottic) Stenosis

Infection can play a part in subglottic stenosis, but the origin of this problem is the prolonged use of endotracheal intubation, which can cause edema, necrosis, and ulcerations of the mucosa. Infection can develop as a result of exposure of the cartilage. Within 48 hours, granulation tissue forms on the ulcerations, leading to a buildup of scar tissue. The scar tissue narrows the airway—hence, the development of subglottic stenosis.[1] The use of endotracheal tubes that are too large and cause trauma to the larynx should be avoided. Trauma may be caused by factors such as intubation, chemical or thermal inhalation, surgery, and external sources. The physician should also be wary of prolonged (longer than 25 days) or repetitive intubation.[1]

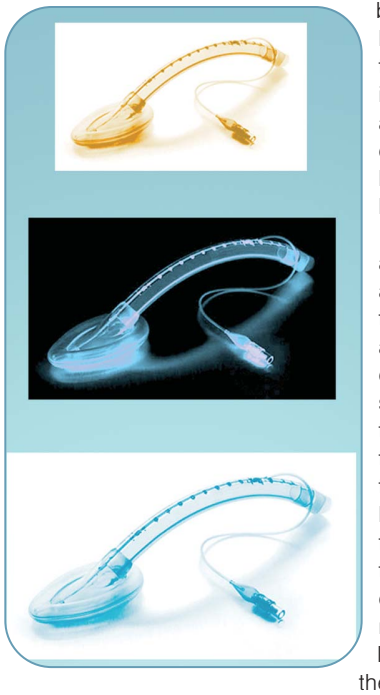
The features of infections in pediatric patients with difficult airways are summarized in Table 4.

Sudden Obstructions: Foreign Body Aspiration

Foreign body aspiration is one of the major causes of mortality in children. The child, usually a toddler, presents with coughing, cyanosis, refractory wheezing, or choking after having eaten small pieces of food—especially peanuts. In 95% of cases, the foreign bodies lodge in the right main bronchus; the other 5% of cases involve the trachea. If a child presents with a foreign body lodged in the airway, the anesthesia provider should take immediate action, regardless of whether the child's stomach is full. This is especially true when peanuts have been ingested because they can easily crumble, making removal difficult; at the same time, the peanut oil can cause an inflammatory response leading to pneumonitis.[6]

The administration of atropine or glycopyrrolate reduces secretions and improves bronchodilation. Antibiotics can be given to patients who are febrile or septic. In cases in which the child has asthma, high doses of corticosteroids or bronchodilators may be beneficial. In some cases, an experienced surgeon who is extremely fast will require only 1 to 2 minutes of paralysis to remove the foreign body or perform a diagnostic endoscopy. In these acute time frame scenarios that require rapid onset and rapid offset of the anesthetic and relaxant, the child can be sedated with an I.V. anesthetic, propofol, and succinylcholine or mivacurium. Longer-acting anesthetics are often required, however. If the child has a full stomach, anesthesia should be administered intravenously; if the child has fasted, anesthesia can be given via inhalation of 100% O_2 with sevoflurane or halothane by mask. The use of nitrous oxide should be avoided because it may cause air trapping distal to the obstruction, assuming it is not complete.

After the induction of anesthesia, the anesthesiologist can intubate the trachea with an endotracheal tube and later allow the surgeon to replace the tube with a rigid bronchoscope. Alternatively, the surgeon can directly insert a ventilating bronchoscope without an endotracheal tube. If the obstruction is in the trachea and the anesthesiologist is faced with a difficult or potentially hazardous intubation that may push the foreign body further in, he or she should transfer responsibility for the airway to the surgeon after induction. The surgeon can remove the foreign body directly with the bronchoscope.[45,46] During ventilation, 3 to 4 mg/kg of topical lidocaine should be applied over the laryngeal structures and tracheal mucosa to dampen the airway reflexes and avert coughing and bronchospasm.[6]



Spontaneous ventilation or muscle relaxation can be used when foreign bodies are removed; there are pros and cons with both methods. Spontaneous ventilation is preferred because this method reduces the risk for airway trauma. Another advantage of spontaneous ventilation is the decreased chance for dislodgment of the foreign body with the control of ventilation. Thus, ventilation can be gently manipulated with limited risk for pushing the foreign body farther down the airway.

One problem with this method is that the depth of sedation of the patient may be inadequate if the stimulation is variable. If the patient starts coughing, becomes tachycardic, or demonstrates a lack of deep sedation, the anesthesiologist can induce deeper anesthesia with gentle ventilation or additional I.V. agents. If bronchospasm occurs during this process, the administration of nebulized albuterol or an I.V. bronchodilator (eg, terbutaline) can relax airway smooth muscle. In cases of refractory bronchospasm, epinephrine is the drug of choice.

If a patient's heart rate, respiratory rate, or muscle tone significantly increases during the extraction of a foreign body, the anesthesiologist should administer—depending on the situation—succinylcholine 1 mg/kg, lidocaine 1.5 mg/kg, ketamine 1 mg/kg, or propofol 1 mg/kg. Supplementation with I.V. lidocaine can help reduce airway reflexes. The bronchoscope with the foreign body must be removed as a unit. During the procedure, the patient's airway should be deeply anesthetized so that a cough or a closing glottis cannot interfere with extraction. In addition, if the lodged foreign body can cause inflammation to the surrounding area (eg, a piece of vegetable or peanut), topical epinephrine diluted to 1:10,000 or 1:100,000 may reduce edema and even help with extraction. Racemic epinephrine diluted to 1:5 can also be used.[6]

Certain scenarios require that the patient be completely motionless while a foreign body is removed from the airway, with muscle relaxation and controlled ventilation. There are a number of described techniques that employ inhalational or I.V. methods. If a muscle relaxant is used, succinylcholine or mivacurium is preferred because both are relatively short-acting drugs. This is a beneficial technique: Extraction is easier because the patient is completely paralyzed, and recovery is faster because a relatively small amount of anesthetic is administered. A risk is that the foreign body may travel farther down the airway or be pushed into a ball valve position, causing a hyperinflated lung.[6]

After complete removal of the foreign body, the anesthesiologist may reintubate the patient (to allow him or her to breathe independently), and then extubate. Close examination of the airway for any remaining fragments of the object is expected. The anesthesiologist or ear, nose, and throat surgeon should actively irrigate excess secretions to prevent postobstructive pneumonia. If inflammation is present, corticosteroids can be administered to reduce swelling. The patient should then be examined closely to ensure that he or she is free of any signs of respiratory edema or infection that may follow the procedure.[6] In cases of sudden obstruction, when intubation is not achieved, rigid bronchoscopic intubation with a Hopkins rod lens telescope may help. Failing this maneuver, the ear, nose, and throat surgeon may opt for a cricothyrotomy—the most rapid method of providing oxygen to the patient when attempts at intubation fail.[3]

Although such severely traumatic situations are rare, in cases of cervical fractures that result in limited movement, a rigid fiber-optic laryngoscope can be optimal. This tool can provide visualization at a 90-degree bend at the tip. Once the laryngeal inlet can be seen, the physician can use a styleted endotracheal tube with the same form as the rigid fiber-optic laryngoscope.[1]

Management of the Case

The patient was given a standard dose (0.2 mg) of nebulized albuterol; later, in the emergency room, he received nebulized racemic epinephrine. He was started on amoxicillin/clavulanate potassium, and because of the urgent nature of the incarcerated hernia, the patient was brought to the operating room. An emergency ear, nose, and throat examination revealed an enlarged tonsillar bed. Anesthesia induction—with propofol, fentanyl, mivacurium, and lidocaine—was facilitated with I.V. midazolam 0.5 mg. A 4.5-mm endotracheal tube was placed, and the patient was maintained on oxygen and sevoflurane. Extubation was uncomplicated, and the patient was discharged home the next day. After a follow-up visit with the ear, nose, and throat surgeon and a complete course of antibiotics, a tonsillectomy was performed 3 weeks later without incident.

Summary

In addition to a wide array of anatomic variations, the pediatric airway can be further complicated by congenital abnormalities, infections, and foreign bodies. The anesthesiologist must act quickly when a patient's condition is deteriorating and also must know when to use the tools that are at his or her disposal.

see **Lesson 242** *page 56*

Lesson 242 *continued from page 55*

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PreAnesthetic Assessment of the Pediatric Patient With a Difficult Airway

Lesson 242: Post-test

Select the single-letter response that most correctly answers the question or completes the sentence.

1. **The larynx in a child is:**
   a. lower in the neck, with its view blocked by a proportionately larger tongue
   b. lower in the neck, but with a clear view because of a proportionately smaller tongue
   c. higher in the neck, with its view blocked by a proportionately larger tongue
   d. higher in the neck, but with a clear view because of a proportionately smaller tongue
2. **In management of the pediatric airway, lifting a child's epiglottis with the laryngoscope blade is complicated by the fact that the pediatric epiglottis is much:**
   a. narrower and angled away from the trachea
   b. wider and angled away from the trachea
   c. narrower and angled toward the trachea
   d. wider and angled toward the trachea
3. **In a child with daytime noisy breathing, a history of cardiac malformations, or Down syndrome, the most useful tool for examining the airway is a:**
   a. tongue blade
   b. nasendoscope
   c. laryngobronchoscope
   d. none of the above
4. **Pierre Robin, Treacher Collins, and Goldenhar's syndromes complicate the airway because they are all associated with:**
   a. micrognathia
   b. mandibular hyperplasia
   c. abnormal breathing
   d. laryngeal polyps
5. **A child with a sudden onset of fever, dysphagia, drooling, and a thick, "muffled" voice, with the head extended and thrust forward, most likely has:**
   a. tonsillitis
   b. epiglottitis
   c. esophageal fistula
   d. foreign body
6. **The most common infectious cause of upper airway obstruction in children is:**
   a. epiglottitis
   b. the common cold
   c. bacterial tracheitis
   d. croup
7. **A febrile patient who has an extremely toxic appearance, fails to respond to racemic epinephrine and glucocorticoids, and has endoscopic findings of subglottic edema with ulcerations and pseudomembrane formation in the trachea, most likely has:**
   a. epiglottitis
   b. the common cold
   c. bacterial tracheitis
   d. croup
8. **In a 4-year-old with a reactive airway or upper respiratory infection, the best approach to manage anesthesia for an inguinal hernia operation is to:**
   a. intubate the trachea
   b. use a supraglottic ventilatory device
   c. use local anesthesia
   d. use a neuraxial block
9. **Aspiration of a foreign body, such as a peanut, is most common in which age group?**
   a. 1 to 4 years
   b. 4 to 6 years
   c. Boys aged 8 to 12 years
   d. It occurs equally in all age groups.
10. **The use of nitrous oxide is contraindicated in cases of foreign body aspiration because nitrous oxide may:**
    a. cause reflex laryngospasm
    b. cause air trapping distal to the obstruction
    c. not be fully effective secondary to the presence of the foreign body
    d. react with the foreign body