

**TITLE: Stridor, Aspiration, and Cough in Children**  
**SOURCE: Grand Rounds Presentation, UTMB, Dept. of Otolaryngology**  
**DATE: December 31, 2003**  
**RESIDENT PHYSICIAN: Frederick S. Rosen, MD**  
**FACULTY PHYSICIAN: Ronald W. Deskin, MD**  
**SERIES EDITORS: Francis B. Quinn, Jr., MD and Matthew W. Ryan, MD**

---

*"This material was prepared by resident physicians in partial fulfillment of educational requirements established for the Postgraduate Training Program of the UTMB Department of Otolaryngology/Head and Neck Surgery and was not intended for clinical use in its present form. It was prepared for the purpose of stimulating group discussion in a conference setting. No warranties, either express or implied, are made with respect to its accuracy, completeness, or timeliness. The material does not necessarily reflect the current or past opinions of members of the UTMB faculty and should not be used for purposes of diagnosis or treatment without consulting appropriate literature sources and informed professional opinion."*

---

## **Stridor**

### **Introduction**

Stridor is a harsh, high-pitched musical sound produced by turbulent airflow through the upper airways. The evaluation must be tailored to the clinical situation, which may range from mild illness to a severe and life-threatening situation.

The larynx has 4 basic functions: ventilation of the lungs, protection of the lungs during deglutition, clearance of secretions by vigorous coughing, and vocalization. An infant's survival depends upon the neurologic and structural integrity of the larynx.

Poiseuille's Law dictates that flow through a cylinder is proportional to the radius to the fourth power. In the healthy neonate, the length of the glottis is 7 mm with a width of 4 mm. The subglottis ranges from 4.5-7 mm in diameter. A narrowing of the subglottis by 1 mm can increase airway resistance 16-fold while decreasing cross-sectional area by 75%.

Bernoulli's Law dictates that, as velocity increases through a constant area, pressure on the lumen wall decreases, thus encouraging collapse of the airway.

There are three zones of the airway characterized by stridor during different phases of respiration. Supraglottic obstruction results in a high-pitched, inspiratory stridor. Obstruction of the extrathoracic trachea, including the glottis and subglottis, is characterized by biphasic stridor with an intermediate pitch. Obstruction of the intrathoracic trachea (including first and second order bronchi) results in expiratory stridor (wheezing). This last area of obstruction is associated with retraction of the sternum, costal cartilage, and suprasternal tissue.

In contrast to stridor, stertor is a low-pitched inspiratory sound produced by nasal or nasopharyngeal obstruction.

## History and Physical Exam

Immediate assessment of the urgency of the situation is vital. As with wheezing, decreased intensity of stridor may indicate either resolution or exhaustion and impending respiratory collapse.

Croup is the most common cause of acute stridor. Laryngomalacia represents the most common cause of congenital chronic stridor.

Croup tends to cause edema most markedly in the subglottis because the respiratory mucosa is loosely attached there.

Birth injury or neurologic abnormalities may suggest TVC paralysis, while a history of intubation suggests subglottic stenosis.

On exam, the child should remain with the parent while the examiner determines the degree of distress. Flaring of the nasal alae and the use of accessory neck and chest muscles are clues to increased respiratory effort. Supraglottic obstruction with air hunger will often cause the patient to sit with the neck hyperextended to improve airflow.

Once one has established that the child is well oxygenated and stable, the exam can proceed. Auscultation over the nose, mouth, neck, and chest can localize the site of obstruction and correlate the stridor with the respiratory phase. Glottic and supraglottic obstruction prolongs inspiration, while bronchial obstruction prolongs expiration.

Positional stridor most frequently results from laryngomalacia, micrognathia, macroglossia, or vascular compression. In all of these cases, improved airflow occurs when the baby is prone with the neck extended.

A weak cry points to either a disorder of the TVC's or poor pulmonary function. While voice changes suggest a laryngeal lesion, a normal voice does NOT rule out a laryngeal cause of stridor. For example, bilateral TVC paralysis is usually associated with a normal voice.

If the stridor is present at birth, one can open the neonate's mouth and pull the mandible and tongue forward. If the stridor lessens, then the obstruction is at the level of the larynx or higher. Passage of a nasal catheter can determine the patency of the nasopharyngeal airway. The placement of an oral airway will bypass the obstruction in choanal atresia. In Pierre-Robin sequence, the placement of a nasopharyngeal airway will maintain the airway until a long-term decision is made, e.g., tracheostomy, mandibular distraction, etc.

One must ALWAYS maintain a high index of suspicion for an aspirated foreign body. In addition, one must remember the possibility of an upper esophageal foreign body that can also result in airway obstruction.

Transnasal flexible endoscopy should be performed in all stable stridorous patients while the patient is awake. Of note, one can also evaluate swallowing this way. While passing a flexible scope it is possible to rule out pyriform aperture stenosis, choanal stenosis, and adenoid hypertrophy. It is also possible to assess hypopharyngeal tone and TVC mobility while looking

for signs of laryngomalacia and/or reflux. Occasionally, one may catch a glimpse of the subglottis.

### **Imaging and Further Workup**

Lateral and A/P neck films are usually the first step in imaging. Inspiration is important on the lateral view; it distends the hypopharynx with air and places the epiglottis in a vertical position while stretching the A-E folds diagonally. Barium swallow is useful to detect aspiration, posterior laryngeal cleft, TEF, or external compression of the airway due to vascular lesions; it can also pick up non-radioopaque esophageal foreign bodies. Of note, it is very difficult to distinguish between posterior laryngeal cleft and garden variety aspiration on barium swallow. The most common extrinsic compressive disorder resulting in stridor is a double aortic arch. This may also be detected on barium swallow as bilateral curvilinear indentations at approximately the level of T-4.

In contrast, a pulmonary artery sling (aberrant left pulmonary artery) results in compression of the right mainstem bronchus and lower trachea. By barium swallow, this will result in an anterior indentation of the upper thoracic esophagus on LATERAL projection. An aberrant subclavian artery, though far less common, can result in the same finding on barium swallow.

CT and MRI may also be useful in suspected cases of vascular compression. CT is very useful in confirming extrinsic compression of the airway by mass effect, particularly in the case of retropharyngeal soft tissue swelling. MRI is superior to angiography in the diagnosis of vascular rings because it images airways and vessels simultaneously. The downside of MRI is that it requires general anesthesia or prolonged sedation. Thus, MRI is best used as a second line when echocardiogram or plain films/barium swallow have not determined the cause of stridor but have suggested a vascular anomaly. The weighting of choice is T1 spin echo with cardiac gating. In the near future (according to the radiologists) ultrafast imaging techniques may minimize the need for sedation and make MRI a far more commonly used modality. Interestingly, Pickhardt found that completely normal A/P and lateral views of the chest essentially rule out a vascular ring. Obviously, radiographs play no role in critical cases of acute stridor.

Of note, ultrasound is an easy and inexpensive way to follow subglottic masses such as a hemangioma.

Airway fluoroscopy is a relatively new modality that has the benefit of being a dynamic study capable of evaluating multiple sites of obstruction simultaneously. Fluoroscopy usually involves 1-2 minutes of radiation exposure at doses of 4-7 mR/min; the average total dose is 10 mR. A thorough fluoroscopic examination involves evaluation of movement of the hemidiaphragms, observation for focal air trapping, and imaging of the airway from the nasopharynx to the mainstem bronchi in the A/P, oblique, and lateral projections. The most common diagnoses established by airway fluoroscopy are subglottic stenosis, laryngomalacia, and airway foreign body. Rudman found that nasopharyngoscopy was far better at detecting supraglottic and glottic lesions, while fluoroscopy was far better at detecting subglottic, tracheal, and bronchial lesions. Plain films were far less sensitive than either nasopharyngoscopy or

fluoroscopy regardless of the site of lesion. Furthermore, fluoroscopy is 90% sensitive for the detection of bronchial foreign bodies, but only 32% sensitive in the detection of tracheal foreign bodies. Interestingly, fluoroscopy was initially used in the diagnosis of obstructive sleep apnea; it is as good or better than nasopharyngoscopy at detecting dynamic oropharyngeal collapse. In addition, fluoroscopy is better than rigid laryngoscopy and bronchoscopy at detecting tracheomalacia.

Rudman concluded that the combination of nasopharyngoscopy and airway fluoroscopy without plain films is the most cost-effective way to evaluate stridor in children (prior to rigid endoscopy).

Usually the history and physical exam, flexible endoscopy, and imaging will result in the correct diagnosis. Diagnostic rigid endoscopy is the gold standard; it is needed when the diagnosis remains in question, the evaluation suggests subglottic stenosis, a second distal airway lesion is suspected, or there is suspicion of a foreign body. While rigid and flexible endoscopy are complementary, rigid endoscopy represents the only means of safely examining the airway distal to the larynx.

## **Endoscopy**

Atropine is useful both to decrease salivary secretions and to minimize the risk of bradycardia. The appropriate dose of atropine is 0.02 mg/kg with a minimum dose of 0.1 mg and a maximum of 0.5 mg/kg. Lidocaine can be applied topically to the larynx to prevent laryngospasm.

The appropriate equipment must be readied before starting the case. One should have an age-appropriate endotracheal tube on hand ( $4 + \text{age}/4$ ) and a size smaller. It is important during the procedure to measure the size of the air passage (especially the subglottis) using either an endotracheal tube or a bronchoscope. Inspection of the anatomic and mucosal contour is also important. However, most importantly, one must maintain a channel to the lungs for ventilation.

The Myer-Cotton grading system uses endotracheal tubes to grade the severity of subglottic stenosis. One passes an endotracheal tube such that the second graduated mark is at the level of the true vocal cords. The tube should then be connected to the ventilatory circuit and the pressure valve closed. The appearance of bubbles around the tube or an audible air leak is noted. The individual's appropriate endotracheal tube size is defined as the largest endotracheal tube that permits a leak at less than 30 cm of water. This is then compared to the age-appropriate endotracheal tube size to assign the Myer-Cotton grade.

After examination of the airway and intubation, esophagoscopy or nasopharyngoscopy can be performed. In addition, the TVC's may be observed during emergence from sedation.

Of note, a recent survey indicated that 72% of pediatric otolaryngologists have incorporated flexible bronchoscopy into their armamentarium. Obviously, a flexible bronchoscope does not allow for ventilation, but it has the advantages of a broad viewing field while allowing for inspection of the peripheral airways. It can also be manipulated through a tracheostomy tube or stoma. The most common indications for flexible bronchoscopy include the diagnosis of stridor in neonates, removal of secretions, inspection of the airway for trauma,

and bronchoalveolar lavage. Pulmonologists have even been using the flexible scope alone for extraction of airway foreign bodies. In cases where the foreign body cannot be retrieved through a rigid bronchoscope due to distal migration, the flexible scope can be inserted through the rigid bronchoscope while maintaining ventilation (similarly, the flexible scope may be passed through an LMA or an endotracheal tube 4.5 or larger). For grasping, one can use ureteral stone forceps passed through the suction channel of a pediatric flexible scope or alongside a neonatal flexible bronchoscope. This requires an assistant to control the forceps.

The overall complication rate for rigid bronchoscopy is approximately 1% and 0.3% for flexible bronchoscopy. The most common complications in descending order are arrhythmia, laryngospasm, pneumothorax, and hemorrhage.

### **Post-extubation Stridor**

Risk factors for post-extubation stridor include endotracheal tube size, the presence of a cuffed tube, the duration of mechanical ventilation, and the presence of underlying airway disease.

The air leak test has been widely used to predict when it is safe to extubate a patient. The test involves using a manometer to measure the minimum amount of air pressure required to produce an audible rush of air around the endotracheal tube as auscultated through a stethoscope placed over the larynx. If the leak only occurs with pressure greater than 20 mm Hg, then the patient has failed the test.

In children with laryngeal edema (e.g., croup) or recent tracheal surgery, the air leak test has been universally successful in predicting a good extubation outcome. In addition, the use of decadron has been effective in facilitating extubation in croup patients. However, there is no clear benefit to steroids in preventing post-extubation complications in normal airways. To date, all prospective studies of steroids in children in this setting have involved decadron; no other steroids have been studied.

Mhanna found that, while the air leak test works for children older than 7 years, it does NOT work for children with normal airways younger than 7. In general, children younger than 7 are far more likely to fail extubation than older patients. Furthermore, Mhanna found that cuffed vs. uncuffed tubes made no difference as far as the incidence of post-extubation stridor in children less than 7, which confirms findings from previous studies. Current guidelines recommend the use of uncuffed tubes in children less than 7.

### **Epiglottitis**

In children, the peak incidence of epiglottitis occurs in the 1-3 year old age group. A review of 407 cases of epiglottitis over 18 years in Rhode Island indicated a dramatic decline in the incidence of epiglottitis among children during the 1980's, with 2/3 of cases occurring in adults. In children, the incidence went from 6/100,000/year to 0.3/100,000/year by 1992, while adults went from 0.78/100,000/year to 3/100,000/year over the same time period.

There was no seasonal variation. Interestingly, no association was found with immunocompromise, though the relative risk of smoking was 2.3.

In children, the most common symptoms were difficulty breathing (80%), a history of fever (57%), and sore throat (50%). In adults, the most common symptoms were sore throat (91%), difficulty swallowing (82%), and difficulty breathing (37%). Stridor occurred in 80% of children, but only 27% of adults. Overall, 86% of lateral neck films were diagnostic.

68% of children versus only 21% of adults received an artificial airway. Risk factors for airway compromise included respiratory difficulty, stridor, drooling, and *H. influenzae* bacteremia. Complaints of sore throat and difficulty swallowing were associated with a milder disease course. 12 deaths occurred as a result of epiglottitis during the study period – 9 were adults.

The important point is that epiglottitis is now rarely seen among children because of the widespread use of the Hib vaccine; it has become essentially an adult disease. *H. influenzae* is no longer the most common cause, and the disease process tends to be less localized to the epiglottis with less risk of airway obstruction. Interestingly, epiglottitis due to thermal injury associated with illicit drug use occurred in 4 patients. This is an important consideration, particularly in adolescent patients.

Nonetheless, management guidelines for epiglottitis have not changed. Severe symptoms mandate prompt rigid endoscopy. In the case of mild to moderate symptoms, the immediate introduction of an artificial airway in ALL children has significantly decreased the number of deaths associated with epiglottitis, but the same is NOT true for adults with mild to moderate symptoms. Unless severe signs or symptoms are noted, adults can be observed in the ICU without an artificial airway. However, deaths occurred during observation in the ER, on the floor, and even in the ICU, so a low threshold for airway placement must be maintained. Regardless, all patients should be treated with a beta-lactamase resistant antibiotic. The use of corticosteroids remains controversial.

## **Aspiration**

### **Introduction**

Aspiration involves penetration of secretions or other material below the level of the true vocal cords. All normal, healthy individuals experience some clinically insignificant aspiration, especially during sleep. Aspiration becomes problematic when the aspirate cannot be cleared or when the aspirate is significantly toxic or voluminous. In children, any significant dysfunction of swallow will also impair the function of the respiratory tract.

Possible complications of chronic aspiration include tracheitis, bronchitis, bronchospasm, pneumonia, and pulmonary abscess.

A swallow consists of 4 phases: the oral preparatory and the oral transit phases, both of which are voluntary; and the pharyngeal and esophageal phases, both of which are involuntary. In infants, squeezing liquid from the nipple (suckling) is part of the oral transit phase.

The swallow reflex begins at 16 weeks gestation and is important in maintaining amniotic fluid balance. Suckle begins in the second and third trimester, thus, suckling is generally poorly

coordinated and ineffective in premature infants while the pharyngeal swallow is generally normal. By 34 weeks gestational age, the premie should be able to suckle feed, though the baby may still have trouble coordinating swallowing and breathing. Suckling is regulated in the medulla and pons. During suckling, peristaltic anterior to posterior tongue motion with compression of the tongue against the soft palate occurs, creating repetitive negative intraoral pressure alternating with nipple compression.

More voluntary control of swallowing becomes possible with maturation of the higher cortical feeding centers. Thus, the oral phase undergoes the greatest change with age, while the pharyngeal and esophageal phases change very little. Chewing normally begins at 6 months of age, achieving 40% of adult efficiency by 6 years.

The afferent limb of the swallow reflex includes the glossopharyngeal, trigeminal, and superior laryngeal nerves. The impulses travel to the swallowing center in the floor of the fourth ventricle. The efferent limb begins in the nucleus ambiguus of the medulla and descends via CN X.

There are 3 mechanisms of airway protection in a normal individual: the laryngeal sphincter, cough, and swallow. There are 3 tiers of the laryngeal sphincter: the epiglottis and A-E folds, the false vocal folds, and the true vocal folds. The swallow helps by clearing material from the larynx and hypopharynx.

Of note, the swallow frequency of an adult during sleep is  $1/60^{\text{th}}$  that of a sleeping preterm infant, who swallows at a rate of 6 times per minute. Infants can further increase this swallowing 8-fold during apneic spells, which serves as a protective mechanism.

Pathologic pulmonary aspiration is secondary either to an abnormality in swallowing or an abnormality in protection of the airway. The causes of aspiration may be either mechanical (i.e., an anatomic change in the upper aerodigestive tract) or functional (e.g., a neuromuscular disorder).

There are 3 different categories of aspirated material: orally ingested, oral and upper airway secretions, or regurgitated gastric contents. The aspiration of oral secretions may be referred to as primary or direct aspiration. The aspiration of gastric refluxate may be referred to as secondary or indirect aspiration. Premature spill from the oral cavity to the oropharynx, incoordination between oropharyngeal motility and glottic closure, ineffective glottic closure, and incomplete bolus transport may all lead to direct aspiration.

### **History/Risk Factors**

Gastroesophageal reflux (GER) is the abnormality most commonly associated with chronic pulmonary aspiration. Pulmonary symptoms can result either from direct injury secondary to aspiration or from reflex mechanisms designed to protect the airway. Signs and symptoms of aspiration due to GER can be obvious or subtle including postprandial cough, regurgitation, emesis, bronchospasm, laryngospasm, central apnea, and bradycardia. In fact, the incidence of significant GER in patients with Acute Life-Threatening Events (ALTE's) is much higher than in normal infants. Near-miss SIDS may represent GER with aspiration during sleep. The classic triad of pathologic GER includes failure to thrive, vomiting, and recurrent aspiration

pneumonia.

Other risk factors that predispose an infant to aspiration include a depressed level of consciousness, deficient swallow mechanisms, general sickness or debilitation, preterm birth, and scoliosis (predisposes child to GER). CNS and neuromuscular diseases frequently affecting swallowing and increasing aspiration risk include cerebral palsy, epilepsy, muscular dystrophy, and intestinal motility disorders.

The feeding history is often key in the evaluation of aspiration. Poor sucking habits or nasopharyngeal reflux during feeds suggest oropharyngeal dyscoordination and may indicate poor swallow coordination. Signs of poor sucking habits include the need for an enlarged nipple hole, frequent choking or gagging with feeds, and failure to thrive. Respiratory symptoms during or shortly after feeding are highly suggestive of aspiration.

Swallowing difficulties frequently arise at approximately 4 months of age as the swallow apparatus begins to elongate, resulting in less protection from aspiration. The soft palate touches the epiglottis until 3-4 months of age. While the gag reflex is strong at birth, it usually weakens by 6-7 months of age.

Prenatal and birth history may also suggest risk factors. For example, polyhydramnios can be associated with defects of the esophagus (e.g., esophageal atresia, ectatic esophagus, or tracheoesophageal fistula). A traumatic delivery may have resulted in recurrent laryngeal nerve injury. A history of upper airway instrumentation can result in pseudodiverticulum or pneumothorax.

One should find answers to the following questions during the history. Is there cough or choking during feeds? Does vomiting occur with the choking? Is there a nocturnal cough? Stridor? Has the child experienced apneas? Is there a hoarse cry?

In addition, existing conditions that may be exacerbated by chronic aspiration include recurrent pneumonia, bronchitis, CF, asthma, failure to thrive, bronchopulmonary dysplasia, ALTE's, and CHF.

### **Physical Exam**

One should inspect (and palpate when possible) all mucous membranes of the nose, oral cavity, and oropharynx. It is also helpful to observe the child during feeding, and one can auscultate the lungs before and after a feed. The observation of nasopharyngeal reflux during feeding indicates swallowing dysfunction and is often associated with aspiration. One should place a finger in the mouth to evaluate the strength and coordination of the suck as well as resistance to deep finger insertion. Neurologic signs and symptoms, such as drooling or excess secretions in the mouth, may also become apparent. In addition, gaseous abdominal distention may be a sign of a tracheoesophageal fistula (TEF).

The examination should include laryngoscopy and evaluation of the cranial nerves.

## **Workup**

Lateral neck and plain chest films are typically the first step. A review of chest x-rays taken of children with chronic aspiration revealed 41% with localized infiltrates, 27% with diffuse infiltrates, 18% with bronchial wall thickening, and 14% with normal films.

A modified barium swallow (MBS) is valuable and is capable of distinguishing between aspiration that occurs directly at the time of the swallow and delayed aspiration occurring during the respiratory cycle but after the swallow. The MBS demonstrates oral, pharyngeal, laryngeal, and esophageal anatomy and can show oral motor dysfunction, pharyngeal incoordination, nasopharyngeal reflux, laryngeal penetration/aspiration, GER, and hiatal hernia. A barium swallow may also detect a laryngotracheal cleft, TEF, vascular ring, esophageal atresia, esophageal stricture, pyloric stenosis, or malrotation, and it may also pick up GER or a hiatal hernia. However, a barium swallow is only 50-85% sensitive and 70-75% specific for reflux.

Other studies which may be helpful include a 24-hour pH probe, gastric scintiscan, and esophagoscopy with or without biopsy. The scintiscan is the study of choice for determining the rate of gastric emptying. Esophageal manometry is difficult to perform in a nonsedated child and is not often used.

The pH probe is the gold standard for the diagnosis of GER. A reflux episode is defined as a drop in the esophageal pH to 4 or less. The number of episodes, as well as the number of episodes lasting more than 5 minutes, are factored in to determine if the reflux is clinically significant (a Euler-Byrne score >50). However, establishing GER does NOT establish aspiration.

A CT or MRI of the brain is useful if CNS problems are suspected. Direct laryngoscopy, esophagoscopy, and bronchoscopy are necessary if the history, physical exam, and above tests do not reveal a cause of chronic aspiration. Endoscopy can assist in the diagnosis of a laryngotracheal cleft, reflux esophagitis, and vascular rings.

## **Treatment**

If anatomic abnormalities such as a cleft or TEF exist, then they must be corrected surgically.

If an endotracheal or tracheostomy tube is present, then it should be removed as soon as it is safe to do so.

The natural history of GER in infants is spontaneous resolution by 18 months to 2 years of age, so the treatment of GER begins with positioning, thickening of feeds, the use of small and frequent feeds, and fasting before bedtime when appropriate. The optimal position for feeding in infants is prone and flat with the entire body tilted 30 degrees postprandially. This position decreases GER, increases gastric emptying, decreases aspiration, and decreases energy expenditure. Sitting may actually exacerbate reflux. Though generally recommended, there is little clinical evidence to support thickening of feeds or smaller, more frequent feeds.

If more conservative measures fail, then medication should be tried. Metoclopramide

increases LES tone and gastric emptying. H-2 blockers and PPI's decrease the acidity of the refluxate. Sucralfate can be used in GER related to delayed gastric emptying from ulcers in or near the pylorus. Failure of 6 weeks of antireflux medications is an indication for antireflux surgery.

Of note, the pH of gastric secretions varies among infants. 1/3 of premies produce little or no gastric acid at birth. Chemical pneumonitis occurs at a pH less than 2.4, while the pH of most formulas is approximately 5. This emphasizes the importance of promotility agents, rather than acid suppression, in the treatment of GER in young children.

In the setting of neurologic problems, one must minimize the complications associated with aspiration. Broad antibiotic coverage against anaerobes should be used in cases of aspiration pneumonia. Good oral hygiene and swallowing therapy are also helpful. If the aspiration is self-limited, one can try an NG tube, a G tube, parenteral feeding, or a tracheostomy until the patient is better.

As far as surgery, a feeding gastrostomy or jejunostomy tube is the most common procedure for severe or irreversible swallowing dysfunction. Gastric fundoplication for severe GER unresponsive to medications will help, but it won't prevent the aspiration of oral secretions. Cricopharyngeal myotomy is appropriate for patients with cricopharyngeal achalasia.

A tracheostomy represents a temporary means of increasing pulmonary toilet, but alone it is not adequate in the setting of chronic aspiration. Vocal fold medialization will help in the presence of a paralyzed TVC. However, in the case of congenital recurrent laryngeal nerve paralysis, surgical procedures on the larynx should be postponed since the nerve function will often recover.

The goal of treatment in chronic aspiration is to decrease the number of episodes of aspiration pneumonia, prevent acute and chronic bronchopulmonary complications, decrease hospitalization and nursing care requirements, and improve the quality of life for both the patient and the family.

Laryngeal diversion and separation represent the most definitive procedures for chronic aspiration. These procedures are indicated for severe aspiration due to laryngeal incompetence that is NOT expected to recover (e.g., central neurologic deficits). Though it is theoretically possible for these patients to learn esophageal speech, phonation generally does not occur. Examples of these procedures are the Lindeman and modified Lindeman procedures.

At the Children's Hospital Medical Center in Cincinnati, they rarely perform laryngeal diversion or separation. In cases of chronic aspiration, the children are fed strictly through a gastrostomy or jejunostomy tube. If reflux is present, they also obtain antireflux surgery. That then leaves the possibility of aspiration of oral and oropharyngeal secretions. Thus, they perform bilateral submandibular gland excision with bilateral parotid duct ligation, which decreases saliva production and aspiration while preserving voice. This also has the advantage of decreasing/eliminating drooling in neurologically impaired children. This almost always obviates the need for a tracheostomy, but a trach can still be performed in those patients who continue to aspirate (rare). In their series of 16 patients, complications were uncommon and

included acute parotitis, sialocele requiring intraoral excision, and one case of chronic parotitis requiring superficial parotidectomy. No patients had problems with increased dental caries or needed to change their dental care. Their workup of children with chronic aspiration typically consists of a MBS, FEEST, and 24-hour esophageal pH probe.

### **Airway foreign body**

Children less than 3 years old have a tendency to put things in their mouths. The National Safety Council (1984) determined that foreign body aspiration was the fourth leading cause of accidental death in children age 1-3 years, and the third leading cause of accidental death in infants less than 1 year. Foreign body aspiration is twice as common in boys.

It is important to acknowledge that esophageal foreign bodies can also cause symptoms of respiratory compromise via compression of the trachea. This occurs in up to 10% of cases of esophageal foreign body. In the case of caustic ingestion, the presence of respiratory distress is highly predictive of severe digestive lesions.

Vegetable matter is the foreign material most commonly found in the pediatric airway (70-80%). Nuts are the most common, followed by carrot pieces, beans, sunflower seeds, and watermelon seeds. The second most common class of aspirated foreign material is plastic (5-15%).

As far as airway foreign bodies resulting in death, 2/3 involve toys intended for children's use. The most common object causing death is a balloon (29%), followed by balls (13%) and marbles (6%). At least two deaths have been reported due to choking on examination gloves given to children in clinician's offices. Aside from conforming objects, spherical objects are the most likely shape to cause choking when aspirated.

The most common site to encounter an airway foreign body is the right mainstem bronchus. Foreign bodies will be found lodged in the bronchi 80-90% of the time.

The classic story involves a brief period of choking, gagging, or wheezing that may be associated with hoarseness or aphonia. Coughing and/or choking is highly suggestive of a foreign body, while respiratory distress is rare. One must always remember the axiom that, "A positive history must never be ignored, while a negative history may be misleading." Signs and symptoms of foreign body aspiration may mimic asthma, croup, and pneumonia. New onset of wheeze in a previously healthy child should heighten suspicion.

The natural history of an airway foreign body involves 3 stages. First, there is a choking episode followed by coughing, gagging, and occasionally complete airway obstruction. This is followed by an asymptomatic interval as the protective reflexes fatigue and irritation subsides, which contributes to a delay in diagnosis (20-50% of cases aren't diagnosed until more than 1 week after the initial aspiration). Finally, signs and symptoms of complications manifest with cough, hemoptysis, pneumoia, lung abscess, fever, or malaise.

Foreign bodies in the larynx or cervical trachea tend to cause inspiratory or biphasic stridor. A prolonged wheeze on expiration suggests involvement of the intrathoracic trachea. A discrepancy between the two sides of the chest on auscultation suggests involvement of a

mainstem bronchus. The classic triad of unilateral wheeze, cough, and ipsilateral decreased breath sounds occurs in less than 1/2 of cases.

Of note, disc batteries contain a high concentration of KOH and NaOH (base, NOT acid), and therefore cause liquefactive necrosis. They begin to cause mucosal damage as early as one hour post-ingestion.

In the setting of a suspected foreign body, inspiratory/expiratory chest films or lateral decubitus films are important. Lateral decubitus films are more useful in younger children who cannot cooperate with the timing of the respiratory cycle. Suggestive findings include air trapping, infection, atelectasis, and failure of the mediastinum to shift when the involved lung is dependent. Inspiratory hypoinflation and expiratory hyperinflation are the hallmarks of a bronchial foreign body. It is important to remember that most airway foreign bodies are radiolucent. However, chest x-ray and exam are commonly normal in the first 24 hours following foreign body aspiration. Thus, history is the most important aspect of the diagnosis, and endoscopy is frequently performed on the basis of a suggestive history, alone.

The key to treatment is recognition of a person in acute airway distress. Complete airway obstruction – indicated by an inability to speak or cough -- is an absolute emergency. Blind finger sweeps are contraindicated because they may further impact the foreign body. Back blows may also impact a foreign body resting below the TVC's in the larynx. Nonetheless, back blows are the appropriate first step in children less than 1 year. In children older than 1 year, gentle abdominal thrusts in the supine position are appropriate. In older children and adults, the Heimlich maneuver is appropriate.

Most of the time, an airway foreign body is not a dire emergency, and endoscopic removal can be scheduled when trained personnel are available, the instruments have been checked, and the techniques have been tested. In addition, one must remember that multiple foreign bodies occur in 5-19% of cases.

## **Cough**

### **Introduction**

Cough represents the most common symptom of respiratory tract disease. The majority of diseases in the first decade of life are respiratory in origin. Respiratory illness accounts for 2/3 of all infections in the first 5 years of life. Cough, in general, is less vigorous in newborns and premature infants.

The respiratory system basically has 4 protective mechanisms: cough, the gag reflex, the mucociliary escalator (which represents the normal clearance mechanism in healthy individuals), and the phagocytic/lymphatic systems. The two functions of cough are to expel foreign material from the airway and to remove excessive secretions from the airway. Cough becomes a factor only when there is an abnormal type or quantity of material to be removed from the airway, *or* when the mucociliary escalator is ineffective.

The stimuli of cough may be categorized into 4 groups: chemical (e.g., cigarette smoke),

mechanical (e.g., vascular rings), thermal (e.g., cold dry air), and inflammatory (e.g., increased mucus).

The afferent pathway of the cough reflex begins with cough receptors, of which there are 4 classes. The slowly and rapidly adapting receptors respond to tactile stimulation and are most numerous at the level of the carina and large bronchi. The C-fiber receptors respond to chemical and mechanical stimulation and are present within the mucosa from the larynx to the alveoli. The pulmonary stretch receptors respond to mechanical forces and are present within the smooth muscle of the airway. The highest cough receptor concentration occurs at the larynx, the lower half of the trachea, the carina, and the mid-sized bronchi. The carina is the single most sensitive site.

Upon stimulation of the cough receptors, the signal passes via cranial nerves IX and X to the upper brainstem/pons. Of note, there is also cortical input such that cough can be initiated or suppressed in the awake patient.

The efferent pathway consists of cranial nerve X and spinal nerves C2-S2, which result in stimulation of the muscles of the diaphragm, pharynx, larynx, intercostals, abdominal wall, and pelvis.

A cough occurs in 4 phases. The inspiratory phase begins with gasping inspiration and ends with glottic closure. The contractive phase occurs with stimulation of the appropriate muscles resulting in contraction against a closed glottic/supraglottic sphincter. During the compressive phase, there is a marked increase in alveolar, pleural, and subglottic pressure. In the expulsive phase, rapid opening of the glottis results in the release of trapped air at flow rates that can reach as high as Mach 0.75 in the adult.

The laryngeal closure reflex is triggered by sensory input from the superior laryngeal nerve. The true vocal cords close first, followed by closure and down-turning of the false vocal cords, followed by closure of the aryepiglottic folds. The closure of the false vocal cords is actually the most important step in preventing premature air escape during cough. Laryngospasm represents a maladaptive glottic closure reflex mediated solely by the superior laryngeal nerve. It can be triggered by tactile stimulation of the endolarynx or mechanical or chemical stimulation of the esophagus.

Increased airway secretions are necessary for an effective cough. However, glottic closure is *not* essential for cough. Intubated patients can cough, albeit with earlier and lower peak flow rates.

## **History**

Age of the child is an important factor. Cough is unusual in neonates and suggests a congenital anomaly, gastroesophageal reflux (GER), cystic fibrosis (CF), or chlamydia pneumonia.

A chronic cough is variably defined as a daily cough greater than 2-3 weeks in duration. Chronic cough affects from 7-10% of children, and its diagnosis rarely requires diagnostic procedures beyond the scope of the primary care physician except in cases of very young

children. In the majority of cases, the diagnosis is based on a positive response to treatment.

Holinger found that in children 18 months old or younger, the three most common causes of chronic cough were aberrant innominate artery, cough variant asthma, and GER. In children age 18 months to 6 years, sinusitis (50%) and cough variant asthma were the most common causes. In children aged 6-16 years, cough variant asthma (45%), psychogenic cough (32%), and sinusitis were the most common causes. A similar study by a pulmonologist that did not break findings down by age found the most common cause of chronic cough in children to be mild to moderately severe reactive airway disease (59%), chronic sinusitis (10%), and GERD (10%).

Involvement in daycare results in increased exposure to upper respiratory pathogens. In fact, recurrent viral upper respiratory infections (URI) represent the number one cause of both acute and chronic cough in children. Preschool age children average 8 or more episodes of URI in one year.

Seasonal variation suggests an allergic etiology. This diagnosis may be confirmed with a response to empiric therapy with an antihistamine.

Malabsorption (i.e., poor growth despite a good appetite), rectal prolapse, and nasal polyps are all signs that point toward CF. In fact, the presence of nasal polyps in a child mandates a sweat chloride test. Most importantly, CF should be considered in any child with chronic cough.

Environmental factors may also play an important role. Cough not associated with a URI is more common in high pollution (e.g., urban) areas. In a large cohort study in Tucson, they found that prenatal smoking doubled the risk of wheezing (and, to a lesser extent, coughing) during the first 3 years of life. However, postnatal parental smoking is NOT associated with wheezing, coughing, or other respiratory symptoms during the first decade of life. Adolescents with cough must be suspected of smoking, themselves.

When taking a history, the specific features of a cough should be determined (quality, timing, duration, and productivity). In addition, establishing the immunization status is important. It is important to distinguish between a persistent cough, which is most typically caused by reactive airway disease or bronchitis, and a recurrent episodic cough, which is most commonly due to recurrent URI.

A barking cough suggests croup.

A frequent, repetitive, honking cough suggests a psychogenic cough. This is most common in adolescents and typically occurs throughout the office visit and has a disruptive effect. Importantly, this is the only type of chronic cough that is completely absent during sleep.

A paroxysmal cough with repeated coughs in quick succession followed by rapid inspiration (“whoop”) suggests pertussis, *but* an infant with pertussis may demonstrate no cough or a cough resulting in facial plethora or cyanosis; the paroxysm in an infant may terminate with vomiting or apnea. In fact, the whoop is uncommon in both infants and children older than 5 years. The paroxysmal stage usually lasts 2-4 weeks, and anywhere from 5-20 coughs may occur with a single expiration. Pertussis typically occurs in epidemic cycles every 2-4 years.

60% of cases occur in children less than 5 years old, and it represents the most frequently reported vaccine preventable disease among children in this age group. The whole cell vaccine was associated with adverse events, which decreased significantly with wide-spread use of the acellular pertussis vaccine in the 1980's. Complications such as pneumonia or severe neurologic sequelae occur in 4-15% of patients with pertussis.

A staccato cough suggests chlamydia pneumonia. This typically occurs in the first 6 months of life, and is usually associated with a prolonged afebrile illness that involves congestion, cough, tachypnea, rales, hyperinflated lungs with diffuse interstitial infiltrates, peripheral eosinophilia, and increased serum immunoglobulins. Conjunctivitis may precede the cough. As in pertussis, the coughing spells may end with cyanosis and/or emesis.

A postprandial and bedtime cough suggests GER. If the cough is associated directly with feeding, this suggests an aortic arch anomaly, laryngotracheal cleft, or tracheoesophageal fistula (TEF). Nocturnal cough, alone, is consistent with GER, sinusitis, allergic rhinitis, or cough variant asthma.

It is unusual for a young child to expectorate sputum, even in the setting of a bacterial pneumonia, since the sputum is usually swallowed. In this case, a "productive" cough may present with vomiting, instead.

Hemoptysis is unusual in children. One should consider bronchiectasis, CF, airway foreign body, pulmonary hemosiderosis, and tuberculosis.

## **Physical Exam**

Young children with pulmonary disease increase their tidal volumes by increasing their respiratory rate, thus, the rate is important to note. In addition, a decreased I:E ratio is strongly suggestive of asthma (or a lower airway process). A normal I:E ratio ranges from 1:2.5 to 1:3.

Listen with and without a stethoscope. A wheeze on forced expiration suggests asthma. Stridor with cough suggests a partial upper airway obstruction.

Sniffing, throat clearing, and hyponasal speech suggest chronic nasal, sinonasal, or adenoid disease. 'Nine' is one of the few words in English with an obligate nasal sound. Thus, nasal airway obstruction can be tested for by having the patient repeat "ninety-nine" with the nose occluded and unoccluded to assess for hyponasality. In addition, the "nasal salute" suggests chronic nasal disease.

In addition, one should observe for rashes, allergic shiners, adenoid facies, and asymmetry of chest motion. On examination of the ears, a hair or cerumen touching the TM can cause cough. Posterior pharyngeal cobblestoning suggests nasal/nasopharyngeal disease.

Digital clubbing is typically seen in chronic suppurative lung disease (e.g., CF, bronchiectasis, and hypersensitivity pneumonia) but is rare in RAD/asthma.

## **Workup**

All children with chronic cough should obtain a P/A and lateral chest x-ray (hopefully, this will have been done before the child reaches you). Other studies that may be obtained as directed by one's history and physical include a sinus CT, a lateral neck film, a barium swallow, inspiratory/expiratory chest films (or lateral decubitus films in younger, less cooperative children), a sweat chloride test, a CBC with differential, eosinophil count, pulse oximeter, ABG, ESR, PPD, PFT's with methacholine challenge, and a sputum sample. In CF, sputum is frequently purulent but rarely foul smelling. A Hansel stain represents a quick and easy way to identify allergy (>5% eosinophils).

According to Holinger, endoscopy was the most useful diagnostic tool in children younger than 18 months. Barium swallow and empiric treatment with bronchodilators were also useful in this age group. In the 18 month-6 year age group, sinus films were the most helpful, followed by endoscopy and a trial of bronchodilators. In the 6-16 year old age group, PFT's with a methacholine challenge were the most useful diagnostic tool, followed by sinus films.

To diagnose pertussis, a sample must be taken from the nasopharynx then grown on Regan-Lowe or Bordet-Gengou agar. The culture is approximately 80% sensitive – less if the patient is on antibiotics. A positive result must be reported to the health department. Both the patient and household contacts should be treated with 14 days of erythromycin or trimethoprim/sulfamethoxazole.

## **More Differential Diagnosis**

One must always maintain a high level of suspicion for an airway foreign body. Cough represents the most common symptom of a bronchial foreign body, occurring in up to 94% of cases. Furthermore, esophageal foreign bodies may also produce airway symptoms, including cough, secondary to tracheal compression.

GER is a frequent cause of cough in the neonate/infant. GER is responsible for chronic cough in 10% of cases of children with normal chest x-rays.

Laryngomalacia typically presents with stridor, but 10% will present with cough. Usually there is a positional history (e.g., the cough occurs when the child is supine and with increased activity).

Postnasal drip as a cause of cough is controversial. Dye studies in the 1930's demonstrated that secretions in the nasopharynx enter the esophagus and not the larynx.

Asthma classically presents with a wheeze, though it may present as cough variant asthma. In almost all children with asthma/RAD, the cough is exacerbated by exercise or exertion (e.g., running or laughing). The cough typically occurs with exertion and during sleep. Most asthmatics develop asthma within the first five years of life. Furthermore, though asthma may present with cough alone, approximately 2/3 of children without a wheeze initially go on to develop classic asthma. The diagnosis of cough variant asthma may be diagnosed either via a trial of bronchodilator therapy – in which case respiratory symptoms should resolve – or via PFT's with a methacholine challenge (the gold standard). Because the onset of asthma generally

occurs before the age of 6, Callahan (Pulmonology) recommends that children older than 6 with a suspicion of asthma/RAD should undergo PFT's. In contrast, children less than 6 with a suggestive history may be given a trial of bronchodilator therapy.

Chang is concerned about the trend towards equating chronic cough with asthma. The use of cough, alone, in the diagnosis of "cough variant asthma" has at least partly contributed to the marked increase in prevalence of asthma over recent years and may be resulting in a lot of overtreatment. She points out that cough in children, more often than not, will resolve spontaneously. Thus, it is difficult to determine the true benefit from a therapeutic trial, and this has been borne out in prospective studies. The treatment of children with cough alone using an inhaled steroid and a bronchodilator showed no benefit over placebo in decreasing cough frequency. These children may have increased cough receptor sensitivity, but they do not have asthma. In the lab, it has been established that the triggers for cough and wheeze are similar, but the physiologic pathways are distinctly different. Cough frequency does not correlate with airway caliber or FEV1. In the absence of wheezing or shortness of breath, persistent nocturnal cough has NOT been correlated with asthma. Chang concludes that a trial of asthma medications may be attempted, but the cough should respond within one week. If there is no response within a couple of weeks, the medication should be abandoned; it is of no use to try increasing the dose.

Bronchitis usually exists in association with other respiratory diseases. Frequently, the trachea is involved concurrently. The pathogen is usually viral. Common causes include influenza, measles, typhoid, pertussis, diphtheria, and scarlet fever. Bacterial infection, if present, usually occurs secondary to the viral infection; *S. pneumoniae* and *H. Influenza* are the most common culprits. Chronic bronchitis in children is unusual in the absence of an underlying pulmonary or systemic disease (e.g., CF, immotile cilia syndrome, etc.). Chronic bronchitis typically presents as a chronic, nonproductive cough occurring after a respiratory infection. It may last for weeks, but usually resolves within 10 days. It is exacerbated by a dry environment, thus fall and winter witness the highest incidence. The usual age of affected children is 5-7 years old. If the bronchitis lasts for more than 2 weeks, one must consider a bacterial infection (particularly pertussis), atelectasis, asthma, CF, an immunodeficiency, or a foreign body.

Bronchiolitis commonly occurs in the lower respiratory tract of children 2 years old and younger. The cause is usually RSV. The characteristic cough is paroxysmal and wheezy, and is frequently associated with tachypnea.

Bronchiectasis refers to a dilation of the bronchi due to inflammatory changes with accumulation of secretions primarily affecting the bronchial wall. Rarely, bronchiectasis can be congenital, but it is usually secondary to chronic pulmonary infections (most commonly CF). Bronchiectasis may also be seen in the setting of GER. Bronchiectasis is characterized by a chronic productive cough with repeat episodes of pneumonia involving the same lung segment (often the left lower lobe). Hemoptysis occurs in 50% of patients, and one may also see clubbing. Of note, bronchiectasis is one of the components of Kartagener Syndrome (also situs inversus, otitis, and chronic sinusitis).

*Mycoplasma pneumoniae* typically presents in school-aged children with paroxysms of cough during sleep.

## References

1. Callahan CW. Etiology of Chronic Cough in a Population of Children Referred to a Pediatric Pulmonologist. *J Am Board Fam Pract.* 1996;9:324-327.
2. Chang AB. Isolated Cough: Probably Not Asthma. *Archives of Disease in Childhood.* 1999;80:211-213.
3. Cohen S, Pine H, Drake A. Use of Rigid and Flexible Bronchoscopy Among Pediatric Otolaryngologists. *Arch Otolaryngol Head Neck Surg.* 2001;127:505-509.
4. Dorn MT, Friedman NR. Stridor, Aspiration, and Cough. *Dr. Quinn's Online Textbook.* January 19, 2000.
5. Gerber ME, Gaugler MD, et al. Chronic Aspiration in Children: When are Bilateral Submandibular Gland Excision and Parotid Duct Ligation Indicated? *Arch Otolaryngol Head Neck Surg.* 1996;122:1368-1371.
6. Goodman TR, McHugh K. The Role of Radiology in the Evaluation of Stridor. *Archives of Disease in Childhood.* 1999;81:456-459.
7. Hartnick CJ, Cotton RT. Stridor and Airway Obstruction. *Pediatric Otolaryngology.* 4<sup>th</sup> Edition. Bluestone CD, et al., ed. 2003:1437-1447.
8. Hotaling AJ, Moynihan GT. Cough. *Pediatric Otolaryngology.* 4<sup>th</sup> Edition. Bluestone CD, et al., ed. 2003:1395-1404.
9. Katzenmeyer KW, Deskin RW. Caustic Ingestion and Foreign Bodies in the Aerodigestive Tract. *Dr. Quinn's Online Textbook.* April 25, 2001.
10. Lamireau T, Rebouissoux L, et al. Accidental Caustic Ingestion in Children: Is Endoscopy Always Mandatory? *JPGN.* 2001;33:81-84.
11. Mayo-Smith MF, Spinale JW, et al. Acute Epiglottitis: An 18-Year Experience in Rhode Island. *Chest.* 1995;108:1640-1647.
12. Meade MO, Guyatt GH, et al. Trials of Corticosteroids to Prevent Postextubation Airway Complications. *Chest.* 2001;120:464S-468S.
13. Mhanna MJ, Zamel YB, et al. The "Air Leak" Test around the Endotracheal Tube, as a Predictor of Postextubation Stridor, is Age Dependent in Children. *Crit CareMed.* 2002;30:2639-2643.
14. Rimell FL, Thome A, et al. Characteristics of Objects That Cause Choking in Children. *JAMA.* 1995;274:1763-1766.

15. Rudman DT, Elmaraghy CA, et al. The Role of Airway Fluoroscopy in the Evaluation of Stridor in Children. *Arch Otolaryngol Head Neck Surg.* 2003;129:305-309.

16. Stein RT, Holberg CJ, et al. Influence of Parental Smoking on Respiratory Symptoms during the First Decade of Life: The Tucson Children's Respiratory Study. *Am J Epidemiol.* 1999;149:1030-1037.

17. Strahan RC, Meyers AD. Aspiration. *Pediatric Otolaryngology.* 4<sup>th</sup> Edition. Bluestone CD, et al., ed. 2003:1405-1412.

18. Swanson KL, Pakash UB, et al. Flexible Bronchoscopic Management of Airway Foreign Bodies in Children. *Chest.* 2002;121:1695-1700.