Stridor, aspiration, and cough are all symptoms of underlying diseases. The focus of this discussion will be on aspiration and cough in the pediatric population. The topic of stridor has been previously discussed in detail; for a more in depth discussion on stridor, please refer to the grand rounds presentation of Dr. Pachigolla (4/98).

**Anatomy and Physiology**

At birth, the neonate’s primary concerns are protection of the airway and oral intake. The neonate is equipped with anatomical and physiological mechanisms to ensure these tasks that are somewhat different than the adult’s. Both airway anatomy and swallowing change with maturation.

The mouth and pharynx are much more compact in the neonate compared to the adult. Until 3 or 4 months of age, an infant’s soft palate and epiglottis are touching. The mandible is relatively small with minimal space between the soft palate and the esophagus. The infant’s tongue touches all borders of the oral cavity.

At birth, the larynx lies at the 2\textsuperscript{nd} and 3\textsuperscript{rd} cervical vertebrae, and the cricoid cartilage is situated at the level of the 3\textsuperscript{rd} or 4\textsuperscript{th} vertebral body. The infant’s hyoid bone and larynx are situated more anteriorly and superiorly than the adult’s. Anatomic proximity and high amount of fat allow for positional stability of the swallowing structures. With maturation, the length and diameter of the trachea increase linearly, and the larynx descends, resulting in vertical elongation of the pharynx and enlargement of the oral cavity. Swallowing difficulties often arise around 4 months of age as the swallow mechanism starts to elongate, leaving the larynx less protection from aspiration. In the adult, the larynx lies opposite the body of the 5\textsuperscript{th} vertebrae, and the cricoid lies opposite the 7\textsuperscript{th} cervical vertebrae.

A recent study using MRI to define the pediatric airway found that the trachea angulates anteriorly, with two limbs seeming to join at an angle (mean 9.9\(^\circ\)) (Reed et al). At birth, this point of angulation is located approximately 22 mm below the sternal notch, ascending to 31 mm above the sternal notch with maturation.
The infant is equipped with primitive reflexes (gag, cough and glottic closure reflexes) that help to protect against aspiration during swallowing. The gag reflex is strong at birth and weakens by age 6 or 7 months. In the newborn, it can be elicited by stimulation of the middle of the tongue. The pharynx reacts by constricting as the jaw and the neck hyperextend to prevent pharyngeal entry of material.

Cough protects the airway by removing abnormal secretions, exudate, or inflammatory products, foreign bodies, and irritating sensations from the respiratory tract (Holinger). The reflex is not always present at birth, with one study showing its presence in only 25% of children less than 5 days old (Miller in Holinger). The reflex is mediated by four different types of cough receptors found between the ciliated pseudostratified columnar epithelial cells from the pharynx to the bronchi. Slow-adapting and rapidly-adapting receptors respond to tactile stimulation in the carina and larger bronchi. C-fiber receptors respond to chemical and mechanical stimuli throughout the respiratory tract. Pulmonary stretch receptors are found in the smooth muscle of the respiratory tract and respond to mechanical stimulation. In all, the highest concentration of receptors is found in the larynx and carina and at other airway bifurcations, with absence of receptors in the alveoli and respiratory bronchioles. Afferent information from receptors in the larynx is primarily carried by the superior laryngeal nerve to the cough center in the medulla. Afferent information from receptors located in the nose and paranasal sinuses is carried by the trigeminal nerve, from the pharynx by the glossopharyngeal nerve, from the external auditory canal (Arnold’s nerve) and tympanic membrane (Jacobsen’s nerve), pleura, and stomach by the vagus nerve, and from the pericardium and diaphragm by the phrenic nerve. Efferent information is carried from the cough center in the medulla by the phrenic and spinal nerves to the diaphragm and intercostal muscles and by the vagus to the musculature of the larynx and tracheobronchial tree.

Coughing begins with deep inspiration, followed by glottic closure, respiratory muscle contraction, rapid airflow, glottic opening and expectoration of mucus and foreign material. During the inspiratory phase, the posterior cricoarytenoid muscle, innervated by the recurrent laryngeal nerves, maximally abducts the vocal cords for wide glottic opening, and the lung volume increases rapidly. During the contractive and compressive phases, the true and false vocal cords close tightly, with the false cords turned down, and the expiratory muscles (diaphragm, abdominal, chest wall, and pelvic floor muscles) contract, resulting in a dramatic increase in intrathoracic pressure. Studies have shown that the down-turned false cords play a much larger role than the true vocal cords in preventing escape of air through the larynx (Holinger). The final phase of the cough cycle is expulsive, with rapid expiration (peak flow of 25,000 cm/sec) and vibration of the vocal cords, supraglottic structures, and posterior glottis. Of note, glottic closure is not essential, as coughing can occur in intubated patients. The cough is less effective as the peak flow rate occurs earlier and is not as high as in those with a competent glottis (Bluestone).

In the glottic closure reflex, the larynx serves as a sphincter to protect the lower airway during deglutition. The majority of the sensory input is carried by the superior laryngeal nerve (SLN), although other special sensory and spinal somatic sensory nerves may contribute. The true vocal cords close first, followed by the false cords, then the aryepiglottic folds. The later two actions are mediated by the thyroarytenoid muscles, which are among the fastest reacting striated muscles in the body. Laryngospasm is a maladaptive exaggerated glottic closure reflex, mediated solely by the SLN, usually triggered by tactile stimulation of the endolarynx (Kidder). Studies have also shown stimulation of the esophagus with acid or with sudden distension may cause laryngospasm.
Normal Age-Related Feeding Behavior

Feeding evolves from reflexive suckling in infancy to voluntary swallowing in adulthood. In utero, swallowing begins at 16 weeks gestation, and plays an important role in maintenance of amniotic fluid balance. Suckling begins in the 2nd and 3rd trimesters. In premature infants, suckling is poorly coordinated and inefficient, though the pharyngeal swallow is present. At 34 weeks gestational age, a premature infant can suckle feed, though he may have trouble coordinating swallowing and breathing.

In the full-term infant, suckle feeding is fully developed and is regulated at a subcortical level in the medulla and pons. The infant’s anatomy is well-suited for nipple feeding; the tongue touches all borders of the oral cavity, and until 3 or 4 months of age, the soft palate and epiglottis are in contact. Suckling is accomplished through peristaltic anterior to posterior tongue motion, compression of the tongue against the prominent soft palate, and creation of repetitive negative intraoral pressure alternating with nipple compression. A normal pharyngeal swallow is initiated as fluid that has collected posteriorly in the pyriform sinuses and valleculae is propelled backward. The soft palate elevates to close off the nasopharynx and breathing ceases as laryngeal elevation, glottic closure, contraction of the pharyngeal constrictors, and relaxation of the cricopharyngeus allow passage of the bolus through the pharynx into the esophagus. The pharyngeal phase of swallowing is similar to that of the adult, except that the pharyngeal swallow occurs with greater frequency and speed in the infant. Peristalsis of the esophageal musculature carries the bolus to the stomach, followed by contraction of the cricopharyngeus to prevent to reflux.

More voluntary control of swallowing becomes possible with maturation of higher cortical feeding centers. The oral phase of deglutition undergoes the greatest changes with growth and development, while the pharyngeal and esophageal stages remain involuntary and unchanged. Chewing begins around 6 months of age and attains 40% of adult efficiency by age 6 years. Growth of the face and skull base, enlargement of the oral cavity and pharynx, and descent of the larynx and hyoid bone facilitate development of adult feeding behavior.

Aspiration

Aspiration is defined as the penetration of secretions below the level of the true vocal cords. Primary or direct aspiration results from penetration of oral secretions, while secondary or indirect aspiration occurs with reflux of gastric contents. Premature spill of food or secretions from the oral cavity into the pharynx, incoordination between oropharyngeal motility and glottic closure, ineffective glottic closure, or incomplete bolus transport can cause direct aspiration. Indirect aspiration can result from an impaired lower esophageal sphincter mechanism or delayed gastric emptying.

Normal barriers to aspiration include the epiglottis, normal swallow reflex, aryepiglottic folds, and apposition of the vocal cords. Epiglottic laxity, large arytenoids, and wide aryepiglottic folds are more common in infants and may predispose to aspiration. Reversal of penetration may be facilitated by contraction of the supraglottic muscles with consecutive swallows (Jolley et al). Thach’s study on pulmonary protective mechanisms in infants showed that during sleep, preterm infants swallow on average 6 times per minute while adults swallow only 6 times per hour. During apneic spells, swallowing may increase by 8-fold.
Factors that predispose to aspiration are CNS disease or prematurity, mechanical factors (nasogastric tube, endotracheal tube, and tracheostomy tube), and anatomic defects (esophageal atresia/stricture, vascular rings, and tracheoesophageal fistula). Possible complications of chronic aspiration include tracheitis, bronchitis, bronchospasm, pneumonia, and pulmonary abscess.

CNS diseases affecting swallowing, protective reflexes, or intestinal motility are thought to predispose children to aspiration. Polendak’s review of respiratory disease mortality in institutionalized mentally retarded children found that those with cerebral palsy, epilepsy, and intestinal motility disorders had significantly higher percentages of aspiration pneumonia (41.7%, 36.7%, and 15% respectively). Children with CNS diseases who have significant oral-motor dysfunction may be unable to initiate an adequate swallow. Drooling in these children, termed sialorrhea, is thought to be caused by inadequate swallowing and poor lip closure (not excess production of saliva). With pooling of secretions and absence of an adequate swallow, aspiration can occur (Gerber). In addition, dysfunction of soft palate elevation can result in nasopharyngeal reflux; Kohda’s study of 72 infants with known aspiration found that 90% with CNS disease and 83% with near-miss SIDS had significant nasopharyngeal reflux. Problems with laryngeal elevation or cricopharyngeal dysfunction are also more prevalent in infants with CNS disease.

**GERD**

Gastroesophageal reflux (GER) occurs when gastric contents pass retrograde into the esophagus. The problem is prevalent among infants and children, but most have physiologic reflux with no clinical consequences (Faubion). The most common symptom of GER in infants is regurgitation, and the most common complication is distal esophagitis. An increased frequency has been found in infants younger than 4 months, suggesting that developmental immaturity of the lower esophageal sphincter (LES) may contribute.

Pulmonary symptoms of GER may result from direct injury secondary to aspiration or from reflex mechanisms designed to protect the airway from stomach contents; GERD should be considered in any patient with chronic cough, stridor, or wheezing. Schatzlein identified the triad of failure to thrive, vomiting, and recurrent aspiration pneumonia as classic symptoms of indirect aspiration. GER-induced airway diseases include laryngitis, pneumonia, reactive airway disease, and central and obstructive apnea. GER-mediated laryngospasm is induced by vagal reflexes in the upper esophagus and pharynx and has been shown to have increased incidence in infants versus adults (Rudolph).

The pH of gastric secretions varies among infants; 1/3 of preterm infants have little or no gastric acid at birth (Gregory). Christie found that severe chemical pneumonitis occurs only when gastric fluid with pH <2.4 is aspirated, although gastric enzymes themselves may be damaging to the laryngeal mucosa. Some authors believe that since the pH of most formulas is 5, respiratory difficulties associated with aspiration in infancy are more likely due to airway obstruction and edema as opposed to chemical pneumonitis (Gregory, Christie).

Children with CNS disorders have been shown to have an increased incidence of GERD. Halpern found the prevalence of GER in children with CNS disease to be significantly higher than children without CNS disease (69% vs. 47%). Schatzlein found that aspiration pneumonia in patients with brain damage was more often due to GERD than to swallowing discoordination. Among premature
intubated infants, the prevalence of GERD was found to be 80% (Goodwin). Patients with scoliosis have also been found to have an increased incidence of GERD (Soundheimer).

**Evaluation of Aspiration**

The history, in addition to covering all organ systems, should include symptoms of aspiration such as cough or choking during feeds, vomiting with choke, nocturnal cough, stridor, apnea, and hoarseness. A complete birth history, including gestational age and weight at birth, difficult delivery, and neonatal medical problems should be obtained. Premature children are more likely to have congenital anomalies of the respiratory or alimentary tracts and/or cricopharyngeal incoordination (Gregory). The child’s pattern of growth and developmental history is important. An attempt should be made to correlate any difficulties encountered during each transition phase of oral feeding (bottle, spoon, cup; purees, junior foods, table foods) to medical and developmental events. One should review the child’s current feeding regimen, typical mealtime, and any associated problems that occur exclusively with eating (coughing, gagging, or wheezing) (Kramer).

Any medical problem may have an effect on feeding, in particular any neurological problems including cerebral palsy, mental retardation, epilepsy and muscular dystrophy. Other medical conditions such as recurrent pneumonia and bronchitis, cystic fibrosis, asthma, failure to thrive, bronchopulmonary dysplasia, ALTE, and congestive heart failure may be associated or exacerbated by chronic aspiration.

On physical exam, a complete head and neck exam, including laryngoscopy and cranial nerve examination, is necessary. Attention to dysmorphic features and neurological dysfunction is important. Examination of the cardiovascular, pulmonary, and gastrointestinal systems is included. Watching a meal and cervical auscultation of a swallow with different textures may demonstrate degree of swallowing coordination.

**Diagnostic studies**

Upper GI series may be useful in helping to discriminate between direct and indirect aspiration and may reveal other conditions predisposing to aspiration (ie, esophageal dysmotility, vascular rings, esophageal atresia, tracheoesophageal fistula, esophageal strictures, GER, pyloric stenosis, and malrotation). The mean sensitivity of detecting aspiration by upper GI was shown by Barish to be 69%.

The videofluroscopic barium swallow is the best procedure to demonstrate the swallowing mechanism (Kramer). It demonstrates oral cavity, pharyngeal, laryngeal, and esophageal anatomy; it can also document oral motor dysfunction, pharyngeal incoordination, nasopharyngeal reflux, laryngeal penetration or aspiration, GER, and hiatal hernia. The speech pathologist can also use it to identify modifications (food texture, consistency and size; patient positioning) to improve swallowing.

GE scintigraphy is the study of choice for determining the rate of gastric emptying. It can also help delineate indirect vs. direct aspiration in addition to demonstrating nighttime and salivary aspiration. Radiation exposure is minimal (using 99mTc), and the test is noninvasive. The positive predictive value has been shown to fall anywhere between 44 and 90%. The test may also be useful to determine the need for pyloroplasty at the time of fundoplication (Faubion).
Manometry has been found to have a sensitivity of 69% in detecting aspiration (Barish). It is useful for the diagnosis of esophageal motility dysfunction and for evaluation of pharyngeal peristalsis and upper esophageal sphincter responsiveness. However, it is difficult to perform in nonsedated children and hence, is not often used for other than research purposes. It may be useful prior to fundoplication to rule out abnormalities in esophageal peristalsis (Faubion).

The 24-hour esophageal pH probe is highly sensitive (92-94%, Barish) for the diagnosis of GER. The test is performed by the gastroenterologist, usually in an inpatient setting. The probe is placed through the nasal cavity, and using fluroscopy, the tip is positioned at 87% of the distance from the alae to the lower esophageal sphincter. Activities, meals, position, and symptoms are recorded every 15 minutes. Reflux is defined as a decrease in pH to less than or equal to 4. The frequency, overall time of esophageal exposure to acid, and longest reflux episode are recorded. The Euler-Byrne formula is used to differentiate symptomatic from asymptomatic GER in children. The score is defined as $x + 4y$, where $x$ equals the number of episodes the pH is less than 4, and $y$ equals the number of times the pH remains less than 4 for greater than 5 minutes. Clinically significant reflux is defined by a score greater than 50 (Bauman).

Another study, somewhat controversial, is the lipid-laden alveolar macrophage index (LLM). Bronchoalveolar lavage is performed to collect alveolar macrophages. Approximately 5 mL of aspirate is collected, then centrifuged and stained with oil red O to identify lipid. One hundred macrophages are counted and rated on a scale from 0 (lowest) to 4 to reflect the amount of intracellular lipid. A score greater than 70 is considered diagnostic for aspiration. Nussbaurn showed it to have a sensitivity of 85% and specificity of 80% for GER in children with chronic pulmonary disease. False positive results are possible from breakdown of endogenous lipids or from toxic responses to medications (cationic amphophilic drugs), and the clearance time of phagocytosed lipid is unknown. In addition, the study cannot discriminate indirect from direct aspiration.

Direct laryngoscopy, bronchoscopy, and esophagoscopy may be useful in detecting laryngeal abnormalities predisposing to aspiration and in assessing damage to upper airway and lower esophageal mucosa from chronic aspiration. In particular, exclusion of a type I laryngotracheal cleft, which may otherwise be asymptomatic, is important, as studies have shown low interarytenoid height to be a predisposing factor to indirect aspiration. Damage to upper airway structures is more apt to occur posteriorly, and common findings include an edematous posterior glottis, hypertrophic interarytenoid tissue, and vocal fold granulomas.

Adjunctive studies include polysomnography, the modified Bernstein test, and pulmonary function tests. PFTs in children with GER-induced pulmonary disease may show airway obstruction, maldistribution of ventilation, and increased airway reactivity (Kurlandsky). The modified Bernstein test was initially developed in adults to distinguish cardiac chest pain from GER-induced chest pain, then modified for children (accounting for symptoms other than heartburn) as chest pain is a rare symptom of GER among pediatric patients. Infusions of 0.1N HCl are infused through a nasogastric tube into the distal esophagus of a monitored patient and alternated with saline for a total of 4 infusions. A positive result occurs when the symptom is present during acid infusion and not present during saline infusion (Bauman).

Bauman developed a diagnostic pathway for pateints with symptoms of GERD. Children with mild symptoms and without complications may be treated empirically without diagnostic testing.
Otherwise, the initial test of choice is the upper GI with video swallow. If no reflux is identified on MBS, a prolonged pH probe is then obtained. If the pH probe is negative and GERD is still suspected, options include DL & B with BAL/LLM and esophagoscopy with biopsy. Antireflux surgery is warranted for mild to moderate symptoms that fail medical therapy or for severe GERD with life-threatening symptoms. For patients with direct aspiration, therapy is dependent on whether or not the larynx is competent.

**Management of Aspiration**

The natural history of reflux in infants is to resolve, so initial management of aspiration is nonsurgical. Eighty-five percent of infants with GER will undergo spontaneous remission by 18 months (Randolph).

The first intervention is modification of food texture and patient positioning. Optimal texture and position for safe feedings is evaluated with the MBS. Placing the child prone, flat, with the entire body tilted 30 degrees postprandially has been shown to reduce GER, improve gastric emptying, decrease aspiration, and reduce energy expenditure (Bauman, Faubion). Thickening formula with rice cereal may decrease the amount of visible regurgitation but has not been shown to prevent actual reflux. Small, more frequent feedings has also not been proven to improve GER in infants.

Medications to treat GER are warranted if more conservative measures are ineffective. Cisapride (0.2mg/kg QID) is a prokinetic that causes indirect release of acetylcholine in the myenteric plexus, resulting in increased LES pressure and improved gastric mobility. Studies have shown improvement of nocturnal cough, wheezing, and irritability with use of cisapride for GER (Olafsdottir). If symptoms persist on cisapride or if esophagitis is present, an H2 receptor blocker (ranitidine, famotidine, or cimetidine) can be added. Omeprazole, a hydrogen pump inhibitor, has been shown to be effective in treating severe esophagitis in pediatric patients unresponsive to H2 receptor antagonists but should only be used short-term due to potential gastrinoma formation.

Indications for surgical intervention include persistent GER despite adequate medical therapy or severe complications (Barrett’s esophagus, apnea, near-SIDS event, uncontrollable asthma, etc.). For unilateral vocal cord paralysis, vocal cord medialization can be effective in preventing aspiration. A cuffed tracheostomy tube does not prevent aspiration; laryngeal elevation, effective cough, and swallowing can be hindered by the tube (Eisele). Anti-reflux procedures include cricopharyngeal myotomy, gastrostomy, Nissen fundoplication, or Thal fundoplication (360° wrap) with or without pyloroplasty.

Intractable aspiration is defined as aspiration not controlled with medical treatment or minor surgery. The patient is incapable of protecting the airway from his or her secretions. Predisposing conditions include cerebrovascular accidents, degenerative neurologic diseases, neuromuscular disorders, intracranial neoplasms, head trauma, anoxic brain injury, laryngeal and hypopharyngeal disorders, and esophageal disorders (Eisele).

In patients with no hope of recovery of laryngeal protective function, “narrow field” laryngectomy may be performed which preserves the hyoid, strap muscles, and as much pharyngeal mucosa as possible. As this procedure is irreversible and results in loss of laryngeal prominence with cosmetic deformity, it is rarely indicated today.
Placement of endolaryngeal stents is another option which is reversible, minimally invasive, and can allow phonation. However, since it requires a tracheostomy, is uncomfortable, and is at a relatively high risk for leak, it is not commonly used.

Laryngeal closure procedures include epiglottic flap closure, vertical laryngoplasty, and glottic closure. The epiglottic flap closure is reversible, allows swallowing and speech, and is at low risk for injuring the true vocal cords. Disadvantages include high rate of flap dehiscence, need for transcervical approach with possible injury to the superior laryngeal nerve, need for tracheostomy, and complication of subglottic stenosis after reversal (Eisele). Glottic closure has similar advantages and disadvantages; it is the most successful in preventing aspiration of the three (93%), although reversal is more difficult and phonation is not possible.

Tracheoesophageal diversion (TED) and laryngotracheal separation (LTS) are the most successful of the reversible surgical techniques for preventing aspiration. Oral intake is possible, but phonation is usually not. There have been, however, limited reports of the use of esophageal speech in these patients. LTS is technically easier to perform than TED and is preferred in patients who have undergone prior tracheostomy. TED is easier to reverse and is associated with fewer complications (Eisele).

**Chronic Cough: Evaluation**

The most common cause of chronic cough in children is URI. However, cough is unusual in the neonate, and children with persistent cough and a normal chest x-ray need prompt referral to an otolaryngologist for evaluation.

The history should include age, character of cough, duration of symptoms, and immunization status. Holinger’s study on children referred to an otolaryngologist for chronic cough showed that the etiology is often related to age. Among children up to 18 months of age, the most common causes of chronic cough were found to be aberrant innominate artery, cough-variant asthma, and GER. Children age 18 months to 6 years were found to have sinusitis as the most common cause of chronic cough (50%), with cough-variant asthma accounting for 27% of cases. From age 6 to 16 years, 45% had cough-variant asthma, 32% had psychogenic cough, and 27% had sinusitis. Nocturnal cough is typical of GER, sinusitis, and cough-variant asthma. Coughing with feeding in the infant suggests a tracheoesophageal fistula or cleft or an aortic arch anomaly. Cough during exercise, cold exposure, or laughing suggests cough-variant asthma. Cystic fibrosis should be considered in a patient with malabsorption, failure to thrive, rectal prolapse, and nasal polyps.

The quality of the cough is also important. An infant with croup may have a seal-like bark, whereas a loud Canada-goose-like honk is typical of psychogenic cough. The cough of pertussis commonly lacks the whoop in infants and may terminate with apnea or vomiting. A staccato cough is typical of chlamydial pneumonia. Wet, productive coughs are typically infectious, while dry coughs suggest foreign body or cough-variant asthma. Hemoptysis is unusual in children but can be associated with bronchiectasis, cystic fibrosis, foreign bodies, pulmonary hemosiderosis, and tuberculosis.
The child’s environment is also important to assess. Children living with siblings and those who attend day care have been shown to have a higher incidence of URIs. Children living in a highly polluted area have been shown to have a higher prevalence of cough without cold. Other studies have shown increased risk of pneumonia and bronchitis in infants exposed to tobacco smoke.

In a child with symptoms of a URI and a persistent cough beyond 14 days, *Bordetella pertussis* should be considered. The classic cough of pertussis is characterized by a paroxysm of coughing followed by rapid inspiration (whoop). Infants may not have the classic inspiratory whoop. Approximately 60% of cases occur in children less than 5 years of age. Complications such as pneumonia and severe neurological sequelae have been shown to occur in 15% and 4% of patients, respectively (Gangarosa).

On physical examination, the presence of a fever should be noted, and height and weight should be measured to check for failure to thrive. The skin should be examined for rashes, and the face noted for allergic shiners or adenoïd facies. A pulmonary exam should begin with inspection for asymmetrical chest motion or digital clubbing. The rate of breathing is important to note in children, as children increase tidal volume by increasing the respiratory rate. One should check for nasal flaring and use of accessory muscles. Auscultation of the neck may be useful if stridor is suspected.

On the head and neck exam, the external auditory canal should be checked for foreign bodies, excessive cerumen, or hair touching the tympanic membrane which may stimulate the cough reflex. Nasal polyps may be found in patients with cystic fibrosis. Cobblestoning of the posterior pharyngeal wall may be seen with chronic post nasal drip. Sniffing, throat clearing, and hyponasal speech are signs of chronic nasal, sinus, or adenoidal disease. Asking the patient to say “99” with and without the nose occluded is helpful in assessing for nasal obstruction. “99” is an obligate nasal sound, and in normal patients, the pitch should change with nasal occlusion.

If cystic fibrosis is suspected, a sweat test should be performed. A sputum gram stain and culture may be helpful but is usually difficult to obtain from a child. To diagnose pertussis, a culture from the nasopharynx, using a dacron or calcium alginate swab, is taken and placed on a Regan-Lowe or Bordet-Gengou agar plate. The culture is approximately 80% sensitive, although the sensitivity is lower if the patient is already on antibiotics (CDC). Positive results must be reported to the health department; both the patient and household contacts should be treated with 14 days of erythromycin (septra for those allergic to erythromycin).

Further studies, based on historical and physical findings, include pulmonary function tests, sinus films, barium swallow, and endoscopy. In Holinger’s study, age also played an important factor in the choice of diagnostic studies. Among infants up to 18 months of age, the most important study was found to be endoscopy, proving to be diagnostic in 56% of the 32 infants. Barium esophagram and empiric therapy with bronchodilators were the other two most frequently informative tests. In children 18 months to 6 years of age, paranasal sinus films were the most useful diagnostic study, confirming the diagnosis in 50%. Also useful were endoscopy and a therapeutic trial of bronchodilators. For children age 6 to 16, the most productive studies were pulmonary function testing with methacholine challenge, followed by paranasal sinus films.

For suspected foreign body aspiration, inspiratory and expiratory films or lateral decubitus films of the chest have been found to have a 67% sensitivity and 67% specificity (Reilly). Findings include air trapping, infection, atelectasis, and failure of the mediastinum to shift when the involved lung is
dependent. However, since chest x-rays and physical exam are commonly normal in the first 24 hours, the decision to perform an endoscopy must often be based on history.

Pertussis is the most frequently reported notifiable vaccine-preventable disease among children younger than 5 years of age. Since the 1980s the incidence has risen, with approximately 7,796 cases reported in the US in 1996. Concerns over the safety of the whole-cell vaccine peaked in the 1980s, fueled by a television program “Vaccine Roulette” and the book *A Shot in the Dark* highlighting adverse events associated with the vaccine. In several countries, including Japan, Sweden, UK, the Russian Federation, Italy, Ireland, and Australia, publicity surrounding these adverse events led to well-organized anti-vaccine movements. In fact, in 1974, the whole-cell pertussis vaccine was eliminated in Japan after 2 children died within 24 hours of receiving the DTP vaccine. From 1974 to 1976, pertussis coverage fell from 80% to 10% in Japan, resulting in an epidemic of more than 13,000 cases and 41 deaths in 1979. In 1981, Japan began using the acellular pertussis vaccine, with subsequent rapid decline in incidence of the disease (Gangarosa). In the US, response to fears over reactions to the whole-cell vaccine led to the implementation of the acellular pertussis vaccine for the 4th and 5th doses of the DTP vaccine in 1991.

**Stridor**

Stridor is Latin for a harsh, creaking sound and is produced by turbulent airflow. Normal breathing is virtually silent, and stridor indicates an obstruction to airflow. The degree and location of the obstruction mandate the character of the stridor. Inspiratory, “wet” stridor occurs with obstruction in the pharynx, tongue, or supraglottis. Biphasic “crowing” stridor can be indicative of involvement of the glottis, subglottis, or extrathoracic trachea, particularly fixed lesions. Expiratory, “wheezing” stridor is heard with obstruction of the intrathoracic trachea or bronchi. As with wheezing in asthma, diminished intensity of stridor may indicate either resolution or exhaustion and respiratory collapse.

Turbulent airflow through the nasal cavities or nasopharynx results in an inspiratory low-pitched sound called stertor or snoring.

**Evaluation**

A careful history should be obtained in the patient with stridor, noting the age of onset, severity, progression, fluctuation, exacerbating and alleviating factors, and related symptoms such as hoarseness, feeding difficulties, and sleep disturbances. Perinatal history is also important. The physical exam begins with vitals, height, and weight, noting the pattern of growth and looking for signs of increased work of breathing. Tachypnea is often the first sign of respiratory distress in children with stridor. Retractions, cyanosis, and rapid respiratory rate may preclude a thorough diagnostic workup before airway intervention. In patients with signs of respiratory compromise, careful noninvasive inspection is necessary to avoid exacerbation. The intensity, pitch, respiratory phase, and effects of positioning on stridor should be noted.

After ensuring that respiratory failure is not imminent, inspection of the airway is performed. Children over 4 years of age can normally tolerate indirect laryngoscopy to detect lesions in the nasopharynx and larynx. Awake flexible fiberoptic laryngoscopy is optimal for evaluating the airway without general anesthesia. Care should be taken in children, ensuring proper monitoring, emergency airway equipment, proper restraint, and topical anesthesia with decongestant. Extreme caution should be
taken in children with suspected epiglottitis; inspection of the airway is prohibited until proper equipment and anesthesia is available.

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