

TITLE: GERD and Aspiration in the Child: Diagnosis and Treatment
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Introduction

The ability to feed is a basic requirement of human life. Infants come into earth through a traumatic birth process, immediately begin to breathe, in most cases cry, and can almost instantly be offered a nipple to begin the complex action of feeding. The coordination and accuracy with which infants feed is amazing. Coordination between muscle groups to propel food into the oropharynx and esophagus, to close off the larynx and respiratory tract, and to whisk the bolus through the esophagus for its destination in the stomach and small intestines is unparalleled by any technological advancement. The following paper will give an overview of the normal swallowing process, the mechanism behind the pathological processes of GERD and aspiration, the diagnosis of these pathologies, and an overview of their treatment. Focus will be on the specialist's role in the management of these children.

Anatomy and Physiology

The swallowing reflex begins at 16 weeks gestation and is important in maintaining amniotic fluid balance. Excessive amniotic fluid is often the first sign that the swallowing mechanism in an infant may be impaired. The ability to suckle begins in the second and third trimester. By 34 weeks gestation most infants have acquired the ability to suckle feed. Premature infants unable to feed generally have difficulty with the oral preparatory phase as the pharyngeal phase is well developed earlier in gestation.

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 mechanisms change with maturation.

At birth, the larynx lies at the 2nd and 3rd cervical vertebrae, and the cricoid cartilage is situated at the level of the 3rd or 4th vertebral body. The infant's hyoid bone and larynx are situated more anteriorly and superiorly than the adult's. Anatomic proximity and high 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 5th cervical vertebrae, and cricoid lies opposite the 7th cervical vertebrae.

The physiology of an infant's swallowing is divided into 4 phases, the oral preparatory phase, the oral transport phase, the pharyngeal phase, and the esophageal phase. The oral preparatory phase of swallowing involves suckle in the infant. This is seen from birth to 6 months of age. This involves the tongue moving back and forward in the mouth creating a rhythmic and peristaltic compression of the nipple between the tongue and hard palate with alternating periods of negative intraoral pressure. The lateral edges of the tongue rise to meet the palate, forming a trough-like configuration to facilitate central passage of the bolus. Posteriorly, the tongue is opposed to the soft palate, holding the fluid in the oral cavity while respiration occurs via the nasopharynx. Next starts the oral transport phase. This begins and ends with a prominent rapid forward movement of the posterior pharyngeal wall that is followed by an upward movement of the anterior tongue and propulsion of the bolus into the oropharynx. The pharyngeal phase begins when the fluid bolus reaches the valleculae and pyriform sinuses and is propelled backward. During this phase, 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 muscle allows passage of the bolus through the pharynx into the esophagus. Laryngeal closure during the pharyngeal phase involves a complex sequence of events beginning at the level of the true vocal folds and proceeding superiorly to the false vocal folds, aryepiglottic folds and epiglottis. The most important and critical component of laryngeal closure is at the glottic level. As the vocal folds close, the arytenoid cartilages tilt up and forward while the base of tongue moves posteriorly effecting closure of the laryngeal vestibule. As this is occurring, the epiglottis moves posteriorly over the airway but fails to completely seal the airway. Epiglottic movement is due to combination of three forces: 1) pressure from the bolus above, 2) the downward pull of muscular forces and 3) the combined pressure of the tongue base moving posteriorly and the larynx elevating. Epiglottic closure prevents entry of food into the laryngeal vestibule and vocal fold closure prevents entry of food into the trachea. The term aspiration refers to the entrance of food into the trachea below the level of the true vocal folds. The pharyngeal phase of the infant is similar to the adult, except that the infant's phase is faster and more frequent than that of an adult. The esophageal phase occurs last. Peristalsis of the esophageal musculature carries the bolus to the stomach, followed by contraction of the cricopharyngeus muscle to prevent reflux.

More voluntary control of swallowing becomes possible with maturation of higher cortical feeding centers. The oral phase of deglutination 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.

Cough protects the airway by removing abnormal secretions, exudates, or inflammatory products, foreign bodies, and irritating sensations from the respiratory tract. The reflex is not always present at birth, with one study showing its presence in only 25% of children less than 5 days old. 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 (Jacobson'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 intercostals 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 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. The final phase of the cough cycle is expulsive, with rapid expiration (peak flow of 25,000cm/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.

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, 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. Studies have also shown stimulation of the esophagus with acid or with sudden distension may cause laryngospasm.

Gastroesophageal Reflux Disease (GERD)

Gastroesophageal reflux (GER) is a common pediatric disorder. It is a descriptive term for the reflux of stomach contents into the esophagus and in mild form is a normal physiological process. It occurs more frequently with younger age, and is the most commonly found in premature infants. The suspected cause of GER is inappropriate relaxation of the lower esophageal sphincter. Symptoms range for postprandial vomiting in the first year of life, to

failure to thrive, esophagitis, and airway obstruction. 50% of infants 0-3 months reflux visibly at least 1 time per day. Only 5% of infants are still refluxing at 10-12 months old. Of these, only 3% of parents view this as a problem. Almost all newborns have evidence of GER by pH probe monitoring, but less than 20% of these episodes result in visible regurgitation. The prevalence of excessive GER in children is approximately 8% as diagnosed by 24 hour pH probe monitoring.

Difficulty in diagnosis of GERD revolves around distinguishing physiologic reflux from GERD. Several pH probe parameters have been established for the diagnosis GERD and are listed below. Pathology is related to the frequency and severity of reflux episodes. Reflux becomes pathological when it leads to insufficient caloric intake, poor growth, esophagitis, or tracheal aspiration. Long term reflux leads to Barrett's esophagitis and with it the increased risk of adenocarcinoma of the esophagus. Clinical symptoms of GERD are regurgitation and vomiting, hematemesis, failure to thrive, irritability, and disturbed sleep. As early as 1884 GER was linked to airway disorders in children. William Osler noted difficulty sleeping when children with asthma ate large meals prior to bed. Possible airway manifestations of GERD include reflux laryngitis, stridor, asthma, apnea, recurrent oxygen desaturation, bradycardia, and sudden infant death syndrome (SIDS). These signs are not sensitive or specific to children with GERD. The diagnosis in children is further complicated because children rarely complain of heartburn and regurgitation. The incidence of acute life threatening events is higher in this age group.

Diagnosis of GERD revolves around history, physical, and several diagnostic tests. Attempts at designing a questionnaire that correlates with results of pH probe testing and other measures of GERD have been unsuccessful. pH probe measurements, barium swallow, manometry, radionuclide milk scans, endoscopy with biopsy, and bronchoscopy with bronchoalveolar lavage for lipid-laden macrophages has been used to diagnose GERD. pH probe measurements are the most widely accepted method of diagnosis. Common pH probe parameter include the number of reflux episodes with $\text{pH} < 4$, reflux index (percent of time the probe is $< \text{pH}$ of 4), longest reflux episode, number of reflux episodes > 5 minutes, and mean duration of sleeping reflux episodes. The reflux index and the number of reflux episodes > 5 minutes have proven best discriminating parameters between reflux patients and controls (Vandenplas et al, 1991). pH probe monitoring does not record alkaline reflux, but is currently the best diagnostic test for detecting GERD. Double channel 24 hour pH probe monitoring with either a symptom-based observation log or cardiorespiratory monitoring is the gold standard in diagnosis of reflux. Placement of one probe just proximal to the GE junction, and one probe in the hypopharynx allows diagnosis of both GERD and laryngopharyngeal reflux (LPR). Barium esophagram has a low sensitivity and specificity for diagnosing reflux. The test is not physiologic, and the patients are imaged for a snapshot of time, allowing only a small view of the entire clinical picture. Panendoscopy with biopsy allows for direct visualization of the mucosa. It is important to obtain esophageal biopsy because 40% of children with normal-appearing esophagus have histologic evidence of esophagitis. Direct examination of the larynx allows detection of increased supraglottic vascularity, laryngeal or subglottic edema, interarytenoid pachydemia, or other signs of GERD. Although widely quoted, the relationship of GERD and LPR are poorly correlated. Bronchoscopy with bronchoalveolar lavage can be obtained during endoscopy. The presence of macrophages has an 85% sensitivity for GERD, and is a very good predictor of aspiration. Esophageal scintiscan is performed using radioactive tracers in milk. Gastric emptying and reflux can be observed in a physiologic state. Delayed imaging over the

lung fields 24 hours later will detect patients with pulmonary aspiration. Sensitivity and specificity vary with experience of the examiners.

Treatment

The treatment of GERD should begin with conservative measures and become progressively more invasive. As 95% of all GERD will resolve by 12 months of age, measures that have very few risks are advocated as first line therapies. These include using smaller, more frequent meals; dietary modifications with formulas composed of medium-chain triglycerides, whey-hydrolysate, soy, or low osmolality formulas; or positioning maneuvers such as positioning the child horizontal prone or at 30 degrees prone after feeds. It is not recommended that children sit at 90 degrees after feeding as studies have shown that GER worsens when sitting up after meals. This is a result of increased intraabdominal pressure generated from bending at the waist. For children with GERD, car trips should be taken in the fasting state when possible. Thickening feeds has emerged as a treatment for GERD. This is likely due to the association of decreased GER with the natural progression of liquid to solid foods. A Cochrane database article from April of 2004 analyzed various studies on the efficacy of thickening of feeds. Although many of the articles showed improvement or trends toward improvement, the authors concluded that no definitive answer for or against thickening feeds could be shown from the literature. They further stated that because of the potential side effects of delayed gastric emptying from thickening of feeds and meals with increased calories, they did not recommend the use of this treatment modality.

Second line therapy for the treatment of GERD revolves around medical control. Cytoprotective agents, prokinetic agents, H₂ receptor blockers, and proton pump inhibitors (PPI's) are all used in the control of GERD. PPI's are much more effective than H₂ receptor antagonist in decreasing acid production. They are limited studies showing efficacy and safety in children taking PPI's. Adult studies do show high efficacy in patients taking these drugs over 6 years. H₂ blockers have apparent safety and efficacy in treating children with reflux esophagitis. Their efficacy over placebo has been proven in randomized controlled trials. For these reasons, they are often the first line medical treatment in GERD. Antacids in the form of aluminum hydroxide have been shown to be as effective as cimetidine for the treatment of peptic esophagitis in children 2 to 42 months when given in high doses. High plasma levels of aluminum in these treatment schemes approach toxic levels, and should deter physicians from this regiment for prolonged treatment because alternate safer medicines are available. Magnesium hydroxide or calcium carbonate is available but unstudied. Prokinetic agents act to increase lower esophageal sphincter pressures, thereby decreasing reflux episodes. While increases in the lower esophageal sphincter pressures have been shown, the number of reflux episodes remains largely unchanged. Transient relaxations of the lower esophageal sphincter account for the continued reflux in patients on prokinetic agents. Cisapride, metoclopramide, bethanecol, and domperidone have been studied in infants and children with reflux. Cisapride showed marginal improvement over placebo, where as the efficacy of other drugs is unproven. Because of problems with cardiac arrhythmias and life threatening events, cisapride was removed from the US market and is available only for special situations in which treatment may be life saving. The efficacy of the other prokinetics in treating children goes largely unproven. Sodium alginate and Sucralfate gels act as surface agents to protect the mucosa of the esophagus and stomach from the damaging effects of gastric acid. Data in children is lacking.

Surgery is considered in children failing maximal medical therapy. The procedure most used by pediatric surgeons in the Nissen fundoplication. Open and laproscopic techniques appear to be equally effective. Many surgeons will add pyloroplasty to the procedure. Success rates vary by study but are around 75%. The most common complications include breakdown of the wrap, small bowel obstruction, infection, pneumonia, perforation, esophageal stricture, and obstruction. Mortality varies from 0% to 4.7%. Re-operation rates vary from 3 to 18%. The potential risks and costs of surgery versus prolonged medical therapy have yet to be studied. Surgical candidates are those who have failed maximal medical therapy and have documented GERD by pH probe monitoring, endoscopy with biopsy, or both. These children often have severe neurological compromise and are high risk for general anesthesia, so a detailed workup is indicated. If airway symptoms are the primary indication for surgery, radiographic studies, bronchoalveolar lavage, esophageal pH monitoring studies, and swallowing studies may impact the decision to proceed with surgery.

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, lack of coordination 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, aryepiglottic folds, normal swallow reflex, 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. 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, prematurity, mechanical factors (nasogastric tube, endotracheal tube, tracheostomy tube), and anatomic defects (esophageal atresia/stricture, vascular rings, tracheoesophageal fistula). Possible complications of chronic aspiration include tracheitis, bronchitis, bronchospasm, pneumonia, and pulmonary abscess.

CNS disease 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 is thought to be caused by inadequate swallowing and poor lip closure, not by excess saliva. With pooling of secretions and absence of an adequate swallow, aspiration can occur. 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 acute life

threatening events had significant nasopharyngeal reflux. Problems with laryngeal elevation or cricopharyngeal dysfunction are also more prevalent in infants with CNS disease.

In evaluation of aspiration, the history should include symptoms of aspiration such as cough or choking during feeds, vomiting with choke, nocturnal cough, stidor, apnea, 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 cricopharyngeal incoordination. The child's pattern of growth and developmental history is important. An attempt should be made to correlate any difficulties encountered during each transitional 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).

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

Physical exam should center on a complete head and neck exam, including laryngoscopy and cranial nerve examination. 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.

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 videofluoroscopic 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 ^{99m}Tc), 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 fluoroscopy, 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).

Recent attention has been given to the dual pH probe monitoring. A probe is placed just distal to the GE junction, and another probe is placed just proximal to the pharyngoesophageal junction to evaluate LPR. Otolaryngologists advocate this test as a better predictor of GER as a cause of aspiration. Further studies are necessary to evaluate norms for comparison, but significant reflux to the proximal sensor and symptoms of aspiration are generally considered diagnostic of GER as a contributor to aspiration.

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. Nussbaum 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 amphiphilic 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.

A relatively new diagnostic modality for aspiration is functional endoscopic evaluation of swallowing (FEES). This test is performed by an otolaryngologist or speech pathologist using a flexible endoscope passed through the nose to the level of Passavant's ridge. Different foods that have been stained for identification are given to the adult or child to swallow. The endoscopist

looks for pooling of the secretions in the vacullae or piriform sinuses, penetration of food to the level of the cords or below, residual food at the false cords, true cords, or subglottic, and the patients cough reflex to the above findings. Patients with penetration of the glottis without adequate cough reflex to clear the penetrations are considered high risk for aspiration pneumonia. The therapist is also able to vary the consistency of the food and re-evaluate to determine if any foods can be cleared safely by the patient. The camera can be withdrawn into the nasopharynx and adequate velopharyngeal closure can be evaluated. Any anatomic abnormalities can be evaluated at the same time. Several studies have been performed using aspiration pneumonia as an outcome. In one study, serial FEES was performed until the patient was able to resume an oral diet. 70% of these patients were able to resume normal diet by the end of the study, and none of these patients developed aspiration pneumonia.

Recent attention has been give to the comparison of FESS to modified barium swallow (MBS) in evaluation of aspiration in the adult and the child. MBS has been considered the gold standard because of long clinical history and multiple studies correlating aspiration by MBS with the development of aspiration pneumonia. Because of this, many of the studies comparing MBS to FEES have listed aspiration with FEES and not by MBS as a false positive. This may not be accurate as it is not established that MBS is a better test than FEES. One study comparing FEES to MBS in children showed 100% correlation between implementation of rehabilitative strategies for subjects randomly assigned to receive both studies. The authors concluded that either study was adequate to evaluate aspiration in children. It is likely that the choice of study has little effect on outcome. FEES is superior to evaluate the anatomy of the swallow superior to the crycopharyngeal muscle. MBS would be superior when abnormalities below the UES might be expected, such as vascular rings or strictures. Children aged 3-8 might more appropriately be evaluated by MBS as they are unlikely to tolerate FEES. Otherwise, local cost and experience should be the determining factor.

Surgical Treatment

The primary cause of aspiration in children is neurological impairment with associated GER. As such, first line therapy is centered on prevention of GER by non-medical means followed by medical treatment as outlined above. First line surgical treatments must be tailored to cause of aspiration. In almost all cases, G-tube fundoplication is the initial step, bypassing primary aspiration and preventing secondary aspiration with one procedure. The results of this treatment are listed above. When this intervention is unsuccessful in preventing aspiration, either due to continued reflux or aspiration of oral secretions, the otolaryngologist is often consulted for further surgical management to prevent pulmonary aspiration.

If the etiology of aspiration is vocal cord paralysis, cord medialization can be effective in preventing aspiration. Although often advocated for management of aspiration, cuffed tracheostomy tubes do not prevent aspiration. Tracheostomy can be helpful to assist with pulmonary toilet in patients with chronic aspiration, but the clinician should realize that the gain in pulmonary toilet is often accompanied by worsened aspiration as a result of decreased laryngeal elevation, decreased effective cough, and poorer swallowing.

Intractable aspiration is defined as aspiration not controlled with medical treatment or minor surgery. These patients are incapable of protecting their airway from their secretions.

Surgical options for these patients are numerous. Laryngeal closure procedures include epiglottic flap closure, vertical laryngoplasty, and glottic closure. The epiglottic flap closure is reversible, allows swallowing and speech, and low risk to vocal cord injury. Injury to the superior laryngeal nerve and flap dehiscence, need for a tracheostomy, and subglottic stenosis after reversal are the major disadvantages to this procedure. Glottic closure is successful in preventing aspiration in over 90% of cases, but reversal is more difficult.

Major procedures to prevent aspiration are the narrow field laryngectomy, tracheoesophageal diversion (TED), and laryngotracheal separation (LTS). Narrow field laryngectomy preserves the hyoid, strap muscles, and as much pharyngeal mucosa as possible. This procedure is irreversible and is rarely indicated today. TED involves suturing the distal portion of the trachea to anotomy made in the esophagus. LTS involves separation and closure of the larynx to create a blind ending passage for food and liquid from the larynx.

Conclusion

Management of the child with GERD and aspiration can vary from simple observation to surgical intervention. Evaluation of the child with dysphagia is complex. Multidisciplinary evaluation is necessary to adequately treat severe dysphagia and aspiration. The otolaryngologist's role can vary from simple visualization of normal anatomy to irreversible surgical management. As many issues in this field are unresolved, it is recommended that the clinician remain abreast of the latest diagnostic and treatment modalities.

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