Dysphagia and Aspiration in Children

James D. Tutor, MD1* and Memorie M. Gosa, CCC-SLP, BRSS2

Summary. Aspiration is a significant cause of respiratory morbidity and sometimes mortality in children. It occurs when airway protective reflexes fail, especially, when dysphagia is also present. Clinical symptoms and physical findings of aspiration can be nonspecific. Advances in technology can lead to early diagnosis of dysphagia and aspiration, and, new therapeutic advances can significantly improve outcome and prognosis. This report first reviews the anatomy and physiology involved in the normal process of swallowing. Next, the protective reflexes that help to prevent aspiration are discussed followed by the pathophysiologic events that occur after an aspiration event. Various disease processes that can result in dysphagia and aspiration in children are discussed. Finally, the various methods for diagnosis and treatment of dysphagia in children are reviewed. Pediatr Pulmonol. 2012; 47:321–337.

Key words: aspiration; dysphagia; pediatrics.

INTRODUCTION

Aspiration, the inhalation of foreign material into the lower airway, has been a significant cause of morbidity and mortality throughout history. Aspiration can be an acute event or a chronic recurrent syndrome. It may occur during oral feeding or may occur after feeding during episodes of gastroesophageal reflux (GER).

Aspiration may occur in children who have problems with dysphagia, difficult or improper swallowing of liquids, solids, or even saliva. When aspiration is chronic and recurrent, the effects on lung development can be devastating leading to pulmonary problems such as recurrent wheezing, recurrent pneumonias, and the development of severe impairment of lung function and pulmonary scarring that can occasionally lead to death. Though the exact incidence of dysphagia in children and accompanying aspiration, is unknown, it is felt to be significant and it is frequently unrecognized by primary care physicians or caregivers as a cause of chronic respiratory symptoms.

In this article, dysphagia in children will be reviewed. First, the normal swallowing mechanism and the protective airway reflexes to prevent aspiration will be discussed. Next, the pathophysiologic events that occur due to aspiration will be reviewed and some of the disease processes in children that may be accompanied by dysphagia are each briefly discussed. Finally, the current methods for diagnosis of dysphagia and its therapy, both current and evolving (including special therapies for salivary aspiration), will be discussed.

ANATOMY AND PHYSIOLOGY OF SWALLOWING

To understand how aspiration can occur, knowledge of the normal anatomy and physiology of the human swallowing mechanism is required. Bosma made significant contributions to the current knowledge of the anatomy of the head and neck in the infant and about its physiologic influence on feeding and swallowing.1–3 The

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swallowing mechanism is part of the upper aerodigestive tract which includes the oral, pharyngeal, and nasal cavities and the larynx. All of these structures working in a coordinated fashion are responsible for normal respiration, swallowing, and eventually speech. Infants’ upper aerodigestive tracts are unique in their anatomic relationships. The major anatomical differences are presented in Table 1 and Figure 1a,b. These anatomic differences in the infant are believed to provide the optimal arrangement for safe, effective nipple feeding. The anatomy of the newborn swallowing mechanism gradually changes over the first months of life as the larynx descends in the pharynx and the upper aerodigestive tract begins to resemble more closely that of the adult by approximately 5 months of age. Sasaki et al. reported on the effects of laryngeal descent pointing out that it allows for oral tidal breathing in the infant and also coincides with the peak incidence of sudden infant death syndrome (SIDS). As the larynx descends, it allows for greater variety of vocalizations but the more caudal laryngeal positioning sacrifices the aspiration protection believed to be afforded to the young infant by the intranaral positioning of the epiglottis during swallowing. Intranasal epiglottic positioning is only possible with the most cephalic positioning of the larynx with the tip of the epiglottis at the level of cervical vertebrae C2–C3.

For diagnostic purposes, swallowing is divided into three distinct phases: oral (to include both oral preparatory and oral transit phases), pharyngeal, and esophageal. What is functional for each of these swallowing phases depends on the individual development of the patient at the time of the assessment. Each of the three phases plays a part in directing a bolus of salivary secretions or ingested food into the esophagus, and not into the air passages.

**AIRWAY PROTECTIVE REFLEXES**

The airway is protected from aspiration by a series of reflexes with sensors in the pharynx, larynx, and esophagus. These mechanoreceptors and chemoreceptors are concentrated over the surface of the pharynx, epiglottis, arytenoid cartilages, and vocal cords. The chemoreceptors are activated by water, as well as by a variety of salts, sugars, and acids. Failure of these protective reflexes allows aspiration to occur from swallowed boluses or material refluxed up the esophagus from the stomach.

The nature of the protective reflex response invited varies as a function of the age of the individual and the region of the pharynx or larynx that is stimulated. Mechanical stimulation of pharyngeal afferent receptors stimulates swallowing at any age. In susceptible human infants, stimulation of the laryngeal chemoreflex, when acid, water, or milk contacts the larynx, can lead to prolonged apnea, rather than coughing and swallowing. This developmental influence is most likely due to central respiratory inhibition. Viral respiratory infections can cause the adult response pattern, that is, coughing and swallowing, to revert to the immature pattern in which apnea predominates. This tendency may explain why prone infants with respiratory viral infections, such as respiratory syncytial virus (RSV), have an increased incidence of apnea and SIDS particularly when lying face downward. When studied in detail, in a premature and a term infant, each experiencing apnea while infected with RSV, the spontaneous apneic events resemble laryngeal chemoreflex-associated apnea. The apnea event in the RSV-infected infants often lasted longer than 30 sec. The apnea was first central and then obstructed (i.e., mixed) and was usually terminated after a series of swallows, or occasionally a cough. Upper airway secretions, which are increased during acute RSV infection, might elicit prolonged laryngeal chemoreflex-associated apnea unless cleared efficiently by swallowing.

Thach discussed the maturation of cough and other reflexes in the neonatal airway. Maturation of the laryngeal cough response leads to an increase in coughing and a decrease in both swallowing and apnea. These changes have been attributed to central processing of afferent (sensory) stimuli as opposed to a reduction in the sensitivity of the larynx or any major change in the

**TABLE 1—Major Oral-Facial Anatomical Differences in Infants and Adolescents**

<table>
<thead>
<tr>
<th>Anatomic location</th>
<th>Infant</th>
<th>Adolescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral cavity</td>
<td>Smaller, due to size and position of mandible</td>
<td>Larger, due to downward forward growth of mandible</td>
</tr>
<tr>
<td></td>
<td>Filled with tongue and fat pads</td>
<td>Presence of teeth and absence of sucking pads creates more space</td>
</tr>
<tr>
<td>Tongue</td>
<td>Housed entirely in the oral cavity</td>
<td>Base of tongue is located in the oropharynx</td>
</tr>
<tr>
<td>Larynx</td>
<td>Approximately 1/3 the size of the adult larynx, minimal gender differences</td>
<td>Vocal fold length is 17–21 mm</td>
</tr>
<tr>
<td></td>
<td>Vocal fold length is 2.5–3.0 mm</td>
<td>Size of the adult larynx is 36 mm for females and 44 mm for males</td>
</tr>
<tr>
<td>Epiglottis</td>
<td>Tip is located at C2</td>
<td>Tip is located at C5–7</td>
</tr>
<tr>
<td></td>
<td>Tip makes contact with soft palate</td>
<td>Tip no longer makes contact with soft palate</td>
</tr>
<tr>
<td>Eustachian tubes</td>
<td>Located at the floor of the nasal cavity</td>
<td>Located posteriorly to the inferior nasal concha</td>
</tr>
</tbody>
</table>
distribution or quantity of receptor sites within the larynx. Laryngeal chemoreceptors in the newborn are the primary defense against aspiration of liquids. As the infant matures, the laryngeal cough response (reflex) becomes more prominent. In adults, the chemoreflexive responses of the larynx continue to provide the primary source of airway protection.19

During most episodes of GER, the gastric contents enter the lower esophagus, but the upper esophageal sphincter remains closed. The refluxed gastric contents are pushed back into the stomach by peristaltic contractions in the body of the esophagus.20 During these episodes of GER, some patients may cough, even though the gastric contents do not enter the pharynx. This coughing may be due to a reflexive increase in salivary secretions that occurs after esophageal acid exposure.21 Patients with abnormal airway anatomy or inadequate stimulation of swallowing may have difficulty handling the increased volume of salivary secretions and therefore aspirate saliva, causing a cough.20 In addition, acid exposure of the esophagus can result in apnea22 or bronchoconstriction.23 When the proximal esophagus is distended vigorously, the upper esophageal sphincter relaxes and allows refluxed stomach contents to enter the hypopharynx.20 Closure of the airway occurs as a result of stimulation of the esophagoglottal closure reflex. This reflex causes anterior movement of the larynx, closure of the vocal cords, and apnea in a manner similar to that seen with swallowing20,24,25 If the refluxed gastric contents enter the pharynx, they are expelled from the mouth or swallowed before respiration is reinitiated. The afferent information that stimulates this reflex is carried in the recurrent laryngeal nerves.20,26,27

PATHOPHYSIOLOGIC EVENTS ASSOCIATED WITH ASPIRATION

Aspiration has the potential to cause permanent damage to the developing lungs of infants and children. Teabeut28 suggested that as the pH of aspirated material drops below 2.5, lung injury increases, with maximal lung injury occurring at a pH of 1.5. The volume of the aspirated material also plays a major role in lung injury. In dogs, 1 ml/kg of acid aspiration produces only mild effects, whereas 2 ml/kg or more of acid aspirate causes serious effects, usually death.29 Histologic findings of aspiration include degeneration of bronchiolar epithelium, pulmonary edema and hemorrhage, focal atelectasis, exudation of fibrin, and acute inflammatory cell infiltrate. Later findings include regeneration of bronchiolar epithelium, proliferation of fibroblasts, and fibrosis.30 Gastric contents instilled into the trachea of dogs appear on the lung surface within 12–18 sec. Extensive atelectasis develops within 3 min. Changes of acute pneumonia occur within hours, and granulomatous changes develop within 48 hr.31,32 Aspiration is most commonly the result of dysphagia (swallowing dysfunction), gastroesophageal reflux disease, or insufficient management of nasal/oral secretions.33 There are several conditions that predispose children to aspiration lung injury (Table 2).
CAUSES OF DYSPHAGIA

The acquisition of the ability to swallow in a normal fashion is a developmental phenomenon. Premature infants are at significant risk for dysphagia but by 34 weeks gestation the swallowing mechanism has generally developed adequately enough so that they are able to transition from gavage feedings to oral feedings given by breast or bottle.34,35 If there is incomplete development or coordination of the suck–swallow–breathe mechanism, aspiration due to dysphagia can occur.36,37 Often this problem occurs in association with a lingering neonatal respiratory illness with or without the presence of tachypnea.38–40 Occasionally, infants born at term may have dysphagia, but this seems to improve over time with growth and further neurological development. Sheikh et al.41 reported on a group of neurologically intact infants born at term without GER who had chronic aspiration due to dysphagia that resolved within 3–9 months.

Dysphagia with aspiration can also occur in young infants due to fatigue of the swallowing mechanism during feedings. This frequently occurs when the infants are pushed to take prolonged or large feedings, particularly toward the end of the feedings.34 Infants placed in their beds with bottles propped in their mouths are at risk for dysphagia and aspiration, especially when they try to suck and swallow when only partially awake.42

Young infants who develop viral respiratory illnesses, such as RSV bronchiolitis, may develop silent aspiration.31 This can lead to unexpected acute respiratory deterioration if these infants continue to eat by mouth. Providing thickened feedings to these infants during the course of their bronchiolitis has been suggested.43

Anatomic problems involving the nasopharynx, oropharynx, and trachea can result in dysfunctional swallowing with resultant aspiration. In some infants with choanal stenosis, respiratory distress may occur only with oral feedings. Due to increased nasal resistance to airflow and the infant’s necessity for nasal breathing, the infant cannot adequately coordinate sucking and swallowing with breathing.34 Treatment consists of complete repair of these anatomic abnormalities with operative intervention if the infant is free of other serious medical conditions or with placement of a tracheostomy if surgical repair is not appropriate or feasible.44–46

Infants with cleft palates and lips are at risk for aspiration due to nasal reflux of feeding causing them to gasp and have aspiration.34 Also, aspiration may occur if food in the nasal cavity falls into a still open airway after the infant has swallowed. Treatment includes proper positioning of the infant during feeding, allowing only short bursts of sucking, suctioning the airway during feeding, and providing supplemental oxygen to the infant during feeding, if needed. Another treatment of the feeding problems of an infant with a cleft palate requires identification of a therapeutic bottle and nipple system that will ensure adequate oral intake despite the child’s poor capacity for sucking.

Laryngotracheal clefts, esophageal atresia, and tracheoesophageal fistulas (TEFs) can result in aspiration. Infants with laryngotracheal clefts, esophageal atresia, and TEFs are at risk for respiratory difficulties, such as coughing, choking, cyanosis, or respiratory distress in association with feeding, and feeding may precipitate aspiration with the subsequent risk of recurrent pneumonia.47 Preoperative therapy involves maintaining a patent airway and preventing aspiration of secretions

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**TABLE 2—Conditions Predisposing to Aspiration in Children**

<table>
<thead>
<tr>
<th>Anatomic</th>
<th>Cleft lip/palate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choanal stenosis</td>
<td>Laryngotracheal cleft</td>
</tr>
<tr>
<td>Cleft lip/palate</td>
<td>Tracheoesophageal fistula</td>
</tr>
<tr>
<td>Laryngotracheal cleft</td>
<td>Craniofacial abnormalities</td>
</tr>
<tr>
<td>Esophageal atresia</td>
<td>Vascular ring</td>
</tr>
<tr>
<td>Tracheoesophageal fistula</td>
<td>Tumors</td>
</tr>
<tr>
<td>Craniofacial abnormalities</td>
<td>Cystic hygroma</td>
</tr>
<tr>
<td>Vascular ring</td>
<td>Syndromes</td>
</tr>
<tr>
<td>Tumors</td>
<td>Pierre Robin</td>
</tr>
<tr>
<td>Cystic hygroma</td>
<td>Beckwith-Wiedemann</td>
</tr>
<tr>
<td>Syndromes</td>
<td>Down (sometimes)</td>
</tr>
<tr>
<td>Pierre Robin</td>
<td>Neuromuscular</td>
</tr>
<tr>
<td>Beckwith-Wiedemann</td>
<td>Perinatal asphyxia</td>
</tr>
<tr>
<td>Down (sometimes)</td>
<td>Cranial nerve or recurrent laryngeal nerve injury</td>
</tr>
<tr>
<td>Neuromuscular</td>
<td>Congenital hydrocephalus</td>
</tr>
<tr>
<td>Perinatal asphyxia</td>
<td>Neonatal intraventricular hemorrhage</td>
</tr>
<tr>
<td>Cranial nerve or recurrent laryngeal nerve injury</td>
<td>Familial dyautonomia</td>
</tr>
<tr>
<td>Congenital hydrocephalus</td>
<td>Moebius syndrome</td>
</tr>
<tr>
<td>Neonatal intraventricular hemorrhage</td>
<td>Myotonic dystrophy</td>
</tr>
<tr>
<td>Familial dyautonomia</td>
<td>Werner-Hoffman disease</td>
</tr>
<tr>
<td>Moebius syndrome</td>
<td>Cornelia de Lange syndrome</td>
</tr>
<tr>
<td>Myotonic dystrophy</td>
<td>Muscular dystrophy</td>
</tr>
<tr>
<td>Werner-Hoffman disease</td>
<td>Myasthenia gravis</td>
</tr>
<tr>
<td>Cornelia de Lange syndrome</td>
<td>Guillain-Barre syndrome</td>
</tr>
<tr>
<td>Muscular dystrophy</td>
<td>Cerebral palsy</td>
</tr>
<tr>
<td>Myasthenia gravis</td>
<td>Vocal cord paralysis</td>
</tr>
<tr>
<td>Guillain-Barre syndrome</td>
<td>Arnold-Chiari malformation (sometimes)</td>
</tr>
<tr>
<td>Cerebral palsy</td>
<td>Gastrointestinal</td>
</tr>
<tr>
<td>Vocal cord paralysis</td>
<td>Gastroesophageal reflux</td>
</tr>
<tr>
<td>Arnold-Chiari malformation (sometimes)</td>
<td>Esophageal motility dysfunction</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Other</td>
</tr>
<tr>
<td>Gastroesophageal reflux</td>
<td>Developmental/immaturity of swallowing</td>
</tr>
<tr>
<td>Esophageal motility dysfunction</td>
<td>Respiratory syncytial virus bronchiolitis</td>
</tr>
<tr>
<td>Other</td>
<td>Endotracheal tubes/tracheostomy tubes</td>
</tr>
<tr>
<td>Developmental/immaturity of swallowing</td>
<td>Foreign body aspiration</td>
</tr>
<tr>
<td>Respiratory syncytial virus bronchiolitis</td>
<td>Collagen vascular disease</td>
</tr>
<tr>
<td>Foreign body aspiration</td>
<td>Obstructive sleep apnea</td>
</tr>
<tr>
<td>Collagen vascular disease</td>
<td>Bottle-propping</td>
</tr>
</tbody>
</table>

The major differences of the VFSS and FEES/FEESST examinations are outlined in Table 3.
and gastric contents. Definitive treatment is surgical repair, with closure of the laryngotracheal cleft, division and ligation of the TEF, and end-to-end anastomosis of the esophagus, if feasible. 47

Infants and children with craniofacial abnormalities that include micrognathia or macroglossia can have problems with recurrent aspiration. The presence of micrognathia results in relative macroglossia that compromises the oral airway and often interrupts, impairs, or prevents successful oral feeding. 34 The infants should be maintained in the prone position so that the tongue and mandible fall forward to relieve airway obstruction at the tongue-base level. 58 When positioning alone fails, tongue-base airway obstruction may be relieved by placement of a nasopharyngeal airway without anesthesia. 49 However, in that same study, of the 35 infants who had placement of nasopharyngeal airways, 40% ultimately needed tube feedings suggesting that airway interventions may negatively affect feeding performance. 49 In some infants, tongue-lip adhesion surgery pulls the tongue anteriorly in the oral cavity, opening the posterior pharynx, thus enabling them to grasp the nipple and to successfully suck and swallow and to experience unobstructed breathing. 34,50 Adverse outcomes of that surgery include dehiscence and need for subsequent procedures. 51 Some have argued that tongue-lip adhesion is detrimental for feeding because it alters tongue mobility and swallowing while others have found improved feeding and weight gain after glossopexy. 52,53 Mandibular distraction procedures in the neonate can improve mandibular size, enhance respiration, and facilitate oral feedings. 48,54

Infants with Down syndrome have protruding tongues and occasionally cleft palates or tracheosophageal fistulas that can put them at risk for feeding difficulties and aspiration. Also, Wells et al. reported on patients with Down syndrome who had midtracheal stenosis. These patients had respiratory difficulty and stridor. 55 Infants with short tracheas would seem to be at high risk for aspiration.

Infants with left-sided congenital diaphragmatic hernia (CDH) have a high incidence of GER, 22%–81%, 56 which could place these infants at possible risk of aspiration. GER is most commonly seen in infants who have had patch closure of their CDHs or if the stomach was located in the thorax. 57 If these predictors are present, performance of a fundoplication at the time of repair of the CDH may help in controlling GER. 58,59 However, long-term follow-up for GER in CDH survivors is mandatory. 57

Vascular rings and pulmonary slings are well-defined congenital anomalies of the aortic arch, brachiocephalic arteries, or pulmonary arteries that cause symptoms due to compression of the airway, esophagus, or both. 60 Respiratory symptoms, such as stridor, barking cough, and wheezing, predominate, but dysphagia may be present as well. Surgical intervention is generally required.

Infants and children with neurologic or neuromuscular dysfunction may develop aspiration. They may be unable to feed by nipple or at the breast due to an inability to coordinate breathing and swallowing, or because they lack adequate bulbar muscle function to successfully feed. 34 They also may have a weak gag mechanism or ineffective cough that predispose them to acute and chronic aspiration. 30 Infants who have a difficult vaginal delivery of their heads with the possibility of a cranial nerve or laryngeal recurrent nerve injury, or infants who have perinatal asphyxia, congenital hydrocephalus, or neonatal intraventricular hemorrhage should also be screened for the presence of feeding difficulties by observation of their feeding by a feeding team that includes a feeding therapist with subsequent testing for dysphagia, if needed. 34

Aspiration can occur in infants and children with endotracheal tube placement or with tracheostomies. Endotracheal tubes can cause remodeling of the palate due to pressure of the tube on the hard and soft palate. After extubation, the infant may be unable to establish a seal around the nipple during feeding due to palato-pharyngeal incompetence, leading to aspiration secondary to nasal reflux of feedings or defective integration of the sucking and swallowing mechanism. 61 The presence of a tracheostomy tube interferes with the swallowing mechanism by preventing the subglottic rise in tracheal pressure and by limiting elevation of the larynx during swallowing. 62–64 The use of a one-way speaking valve has been shown to improve swallowing function in adults and children with a tracheotomy by improving oral and pharyngeal sensation and increasing subglottic pressure during swallowing. The use of these speaking valves have been shown to decrease the occurrence of aspiration in adults. 65 The use of a tracheostomy tube with an inflatable cuff has previously been used by some to hopefully decrease the risk of aspiration of oral liquids and feedings in some children who have dysphagia. Currently, it is recommended that the cuff not be inflated during eating so as to not tether the larynx and prevent its rise. 66 Care must be taken to not overinflate the cuff of these tubes or leave the cuffs continuously inflated since that may lead to ischemia of the tracheal mucosa sometimes with disastrous results such as formation of a TEF or a trachea-innominate artery fistula. 67–69

Acute episodes of aspiration can occur when infants or children swallow volatile or oily liquids such as mineral oil, medium-chain triglycerides, furniture polish, 70,71 or other hydrocarbon-containing liquids. These liquids cause extensive airway mucosal and lung parenchymal inflammation and injury, resulting in pneumonia with the possibility of acute respiratory...
distress syndrome, and pulmonary parenchymal fibrosis. Infants and children, particularly those younger than 4 years old, are at the highest risk to acutely aspirate foreign bodies. Also, older children occasionally aspirate foreign bodies. However, the relative risk and the types of foreign bodies that are aspirated change. This can result in asphyxiation and death or post-obstructive pneumonia and eventually bronchiectasis.

**SYMPTOMS OF ASPIRATION**

Aspiration may occur due to dysphagia, in children with some neurological conditions or with weak musculature, or in those with disorders of gastroesophageal motility and sphincter tone. They may present to their physicians with complaints such as wheezing that is poorly responsive to appropriate therapies, chronic cough, recurrent pneumonia, atelectasis, bronchiectasis, pulmonary abscess, pulmonary fibrosis, bronchiolitis obliterans, apnea/bradycardia/acute life-threatening events, failure to thrive, stridor, or laryngitis/hoarseness. Animal studies have suggested that microaspiration can cause symptoms directly from airway inflammation as well as predisposing to or accentuating airway hyperreactivity. Reflex bronchoconstriction from esophageal acidification has been observed in both animals and humans. Esophageal acidification can also increase nonspecific airway hyperreactivity without necessarily causing a change in baseline pulmonary mechanics.76

Infants and children with an absent or ineffective cough reflex may have silent aspiration and have findings of only increased respiratory mucus, congestion and chronic wheeze or rhonchi, recurrent bronchitis, or recurrent pneumonia.

**PHYSICAL EVALUATION FOR ASPIRATION**

It is important that the clinician observe the infant or child eating and auscultate the chest and back both before and after feeding for crackles, wheezes, “wet” upper airway noises, and “wet” voice quality. Attention should be given to nasopharyngeal reflux, difficulty when sucking or swallowing, and associated coughing and choking. Drooling or excessive accumulation of secretions in the mouth suggests dysphagia.

**RADIOGRAPHIC EVALUATION OF ASPIRATION**

The initial test for a patient with chronic or recurrent respiratory symptoms often is the chest radiograph. In a group of 22 children with recurrent aspiration, the chest radiograph was normal in 14% and revealed only bronchial wall thickening or hyperinflation in 18%. The radiographs in the rest of the children revealed diffuse (27%) or localized (41%) infiltrates. Infiltrates in infants with recurrent aspiration can be in dependent areas such as the upper lobes and the posterior areas of the lower lobes. Infiltrates are frequently not associated with fever typical of infectious causes. Chest radiographs are largely insensitive to early changes of lung injury.

Computed tomography scans, particularly high-resolution images, are more sensitive in the detection of early airway and parenchymal disease in children who aspirate, particularly in those with lipoid pneumonia. Findings of bronchial wall thickening, air-trapping, bronchiectasis, ground-glass opacities, and centrilobular opacities (“tree in bud”) are common in children who chronically aspirate.

**DIAGNOSIS OF CHRONIC ASPIRATION DUE TO DYSPHAGIA**

The pediatric assessment for dysphagia begins with a thorough review of the patient’s history, including medical, developmental, and feeding history.

Clinical feeding assessment usually includes observation of the parent and child during feeding, oral peripheral examination, communicative behavior, and observations of the child before and after feeding. It may also include a screening test for aspiration such as the 3-ounce water swallow challenge (3-oz WSC). Suiter et al. reported on the sensitivity and specificity of the 3-oz WSC for children ranging in age from 2 to 18 years of age. They utilized the results of fiberoptic endoscopic evaluation of swallowing (FEES) as the outcome variable and standard by which the results of the 3-oz WSC were compared. The sensitivity for predicting aspiration using the 3-oz WSC was 100% with a specificity of 51%. The sensitivity and specificity of the 3-oz WSC for predicting which children could safely intake thin liquids was 100% and 44% respectively. Based on these results, the authors suggested that successful accomplishment of the 3-oz WSC allows for the safe oral intake of thin liquids as well as pureed and soft oral solids without the need for further swallowing assessment. They did suggest, however, that the 3-oz WSC was not the best screening tool for identifying children who are at risk for aspirating thin liquids due to the high false positive rate and low specificity of the test.

Instrumental assessment is necessary for definitive diagnosis of swallowing dysfunction and aspiration. Instrumental assessment for dysphagia might include the following: videofluoroscopic swallow study (VFSS), also commonly known as the modified barium swallow study (MBS), fiberoptic endoscopic evaluation of swallowing with or without sensory testing (FEES or FEESST), sonography, manometry, scintigraphy, and cervical auscultation. VFSS and FEES/FEESST are the most common instrumental assessments for pediatric pulmonology.

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objective assessment of oropharyngeal swallowing function in the pediatric population (Table 3). Neither procedure has been established as a “gold standard” for the detection of aspiration. Rao et al.\(^8\) compared VFSS and FEES to determine their sensitivities and specificities. When each was individually used as a “gold standard” for the detection of aspiration, FEES was found to have a higher sensitivity, but VFSS was found to have a higher specificity in their study (Table 4). Several investigators have reported on the reliability of FEES as compared to other diagnostic tests for aspiration, primarily VFSS in pediatric populations and have found it to be a reliable and safe exam for diagnosing dysphagia. It has good agreement with VFSS in that population, especially when trying to detect aspiration.\(^8\)–\(^9\) However, currently data is only available in adults, not in children regarding the sensitivity and specificity of FEES to detect aspiration (Table 4).

**VFSS**

The VFSS is the only instrumental assessment that provides visualization of the anatomy of the oral cavity, pharynx, larynx, and upper esophagus, as well as the function and integration of all four areas during the dynamic process of swallowing. It provides the most thorough assessment of swallowing function and of compensatory measures to improve swallowing function in the pediatric population. It continues to be the “assumed” gold standard in adults for objectively assessing oropharyngeal swallowing function. VFSS is generally considered to be a reliable and safe method for diagnosing dysphagia in the pediatric population. The test, however, potentially employs a significant amount of radiation exposure to the brain. The benefits from use of the test should be weighed against its risks, particularly if its use involves small infants or in children with significant brain injuries. Currently, no data is available regarding its sensitivity and specificity for detecting aspiration in children and, only one study has reported on its sensitivity and specificity in adults.\(^3\)–\(^10\)

VFSS is accomplished by age/developmentally appropriate positioning of infants and children within a fluoroscopy suite in a specialized seating device that provides adequate trunk, neck, and head control. Presentation of test materials and viscosity of test materials are also presented in an age/developmentally appropriate format.\(^8\) For infants younger than 6 months, liquid from a bottle is presented. For infants older than 6 months and children, liquid is given from a preferred method (in graded quantities if cup/straw drinking), and thicker consistencies and chewable foods are offered when developmentally appropriate.\(^8\)

The ultimate goal of the VFSS is to determine the physiologic cause of the dysphagia symptom (aspiration

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### TABLE 3—VFSS Versus FEES/FEESST

<table>
<thead>
<tr>
<th>Component</th>
<th>VFSS</th>
<th>FEES/FEESST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visualizes</td>
<td>Radiographic image of oral cavity, pharynx, larynx, trachea, and upper esophagus during all four stages of the swallow in real time</td>
<td>Soft tissue components of pharynx and larynx before and after swallow, including any soft tissue anomaly; unable to visualize pharynx during the swallow due to white-out with pharyngeal constriction during swallow</td>
</tr>
<tr>
<td>Test materials</td>
<td>Small amounts of barium liquids, semi-solid barium consistency, and solid consistency with barium coating</td>
<td>Real food items colored to provide contrast</td>
</tr>
<tr>
<td>Duration</td>
<td>Limited to 2–4 min due to use of fluoroscopy</td>
<td>Duration of entire meal (if necessary)</td>
</tr>
</tbody>
</table>

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### TABLE 4—Sensitivity and Specificity of Tests to Detect Aspiration

<table>
<thead>
<tr>
<th>Measure</th>
<th>Comparative measure</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Refs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberoptic endoscopic evaluation of swallowing (FEES)</td>
<td>VFSS</td>
<td>70–96% for detecting aspiration in adults</td>
<td>87.5–100% for detecting aspiration in adults</td>
<td>88,89,90–93</td>
</tr>
<tr>
<td>Videofluoroscopic Swallow Study (VFSS)</td>
<td>FEES</td>
<td>100% for detecting aspiration in adults</td>
<td>63% for detecting aspiration in adults</td>
<td>88,94–96</td>
</tr>
<tr>
<td>Lipid-laden macrophage index (LLMI)</td>
<td>Battery of other clinical and imaging exams</td>
<td>69–98.6% for detecting aspiration in infants and children</td>
<td>78–79% for detecting aspiration in infants and children</td>
<td>105–107</td>
</tr>
<tr>
<td>Blue dye test (BDT)</td>
<td>VFSS</td>
<td>38–79% for detecting aspiration in adults</td>
<td>28–100% for detecting aspiration in adults</td>
<td>124,126–132</td>
</tr>
<tr>
<td>Modified Evans blue dye test (MEBDT)</td>
<td>FEES</td>
<td>82–95% for detecting aspiration in adults</td>
<td>38–100% for detecting aspiration in adults</td>
<td>124,126,127,128–132</td>
</tr>
</tbody>
</table>
or laryngeal penetration, nasopharyngeal backflow, swallow trigger, and pharyngeal residual) and then identify the most appropriate treatment strategies to allow the safest and most appropriate intake of calories for infants and children. When choosing management strategies, the clinician must be mindful of the developmental level of the patient as well as the patient’s cognitive status.82,97

FEES/FEESST

FEES enables direct visualization of soft tissue structures before and after the swallow.33,98 For infants and children, the speech-language pathologist or physician passes a small flexible endoscope through the patient’s nose and positions it for optimal visualization of the hypopharynx and larynx. Test materials are colored to provide improved visualization of the foods and liquids as they are swallowed.99

During feeding, FEES can identify oropharyngeal dysfunction that occurs before the swallow such as spillover and laryngeal penetration or aspiration. During the swallow, pharyngeal constriction causes white-out and briefly totally blocks all visualization of oropharyngeal structures. After the swallow, residual material can be seen, and the presence of laryngeal penetration or aspiration from the residue can be noted. Additionally, aspiration during the swallow may be identified with visualization of food or liquid in the trachea after the swallow.99 Treatment strategies can then be tested and a treatment plan made based on information collected from the history, clinical feeding assessment, and FEES.

FEESST gives the examiner information about swallowing dysfunction and about the laryngeal adductor reflex (LAR). The LAR, which is vital for airway protection, is stimulated by providing controlled air pulses to the aryepiglottic folds through the port of a flexible laryngoscope. By stimulating them with increasing pressure in the form of the air pulse, the examiner gains information about laryngopharyngeal mechanosensitivity. Normal LAR is elicited with <4.0 mmHg of air pulse pressure; anything greater than that is considered abnormal. Abnormal laryngopharyngeal mechanosensitivity can result from a variety of conditions, including GER disease.100–104

OTHER DIAGNOSTIC TESTS OF ASPIRATION

The calculation of a quantitative index of lipid-laden macrophages (LLM) in bronchoalveolar lavage samples has been evaluated repeatedly as a test for chronic aspiration, but results have been conflicting (Table 4). Colombo and Hallberg105 reported on the use of an LLM index in a group of children suspected to have aspiration during feeding. Using a 0–400 scale, they reported that children with suspected aspiration had an LLM index >86, with the highest LLM index in the “nonaspirator” group being 72. Furuya et al.106 reported that a LLM index >165 had a 98.6% sensitivity, 78% specificity, and 87.8% overall accuracy as a diagnostic test for aspiration in a group of 112 children. A LLM index >90 for “aspirators” versus “nonaspirators,” was retrospectively reviewed in 1999. The sensitivity and specificity of the test were 0.69 and 0.79, respectively.107 Elevated LLM indexes have been found in children, not suspected of aspirating who have various diseases including cystic fibrosis, those receiving intravenous lipid preparations, those with pulmonary fat embolism in sickle cell disease, and those with endogenous lipid pneumonia from bronchial obstruction.108–112 The LLM index is reportedly poorly reproducible due to inter- and intra-observer variability in calculating the index.113 Finally, the LLM index may also vary depending on the amount of time since the last aspiration event.114 Despite all these limitations, a LLM index may provide supporting evidence of aspiration in select patients.115

Some children may have aspiration of saliva with continued respiratory symptoms even if other causes of aspiration from oral feeding and GER have been effectively treated. The radionuclide salivagram is used to try to detect salivary aspiration. A small quantity of radiotracer is placed in the buccal pouch, and serial images are taken until the tracer clears the mouth. Activity in the trachea or bronchi indicates aspiration. Though it has been reported that the salivagram is a sensitive test for salivary aspiration, there was only 26%–28% prevalence of positive salivagrams in children suspected of aspiration seen in three retrospective studies.116–118 Salivagrams also have poor correlation with other tests of aspiration such as barium video-fluoroscopy and milk scans.119 In a study evaluating the ability of salivagrams to predict the need for laryngotracheal separation (LTS), there was no significant correlation noted between the salivagram result and days hospitalized due to respiratory symptoms.120 However, Finder et al.121 reported the use of serial salivagrams to titrate continuous positive airway pressure given via tracheostomy to decrease salivary aspiration. Thus, while the salivagram is useful for the detection of aspiration in some patients, further studies need to be conducted to evaluate its sensitivity and specificity. This has not been done to date due to the lack of a “gold standard” exam for detection of salivary aspiration to which the salivagram can be compared.

Colored dye placed on the tongue (blue dye test) or mixed in the foods (modified Evans Blue dye test) of children with endotracheal tubes or tracheostomies was previously frequently used to determine whether chronic aspiration into the pulmonary airway is occurring.
(Table 4). Finding of the dye in tracheal secretions suctioned from the airway tube is presumptive evidence of aspiration. Amanntéa et al.\textsuperscript{122} reported on a group of 50 endotracheally intubated children who had Evans blue dye placed in their oral cavities. Two tracheal aspirates were obtained at 5- and 30-min intervals. The prevalence of aspiration was reported to be 28%.

Several researchers, who studied only adults, have compared the accuracy of dye studies with other diagnostic studies of aspiration such as the VFSS and the FEES. Four of the studies reported the false negative rates of the dye studies to be 50–61% but with specificities near 100%. In those studies, food of various consistencies for VFSS and FEES were dyed blue, and the tracheostomy tube was then suctioned.\textsuperscript{123–126} Belafsky et al.\textsuperscript{127} reported on the use of a modified blue dye screening protocol and found the modified Evans blue dye test to have slightly higher sensitivity and specificity for detecting aspiration than the unmodified blue dye test (Table 4). Dye studies using large volumes and more frequent administrations were previously reported to serve as a screening test for children with possible aspiration.\textsuperscript{79} Using either VFSS or FEES to document aspiration, several reports have examined swallowing function in pediatric patients with tracheostomies and have reported on the incidence, prevalence, and symptoms of dysphagia found in this population. None of these studies reported on the use of the blue dye test or the modified Evans blue dye test in these children. Presently, data for determining the sensitivity and specificity of the blue dye test or the modified Evans blue dye test to detect aspiration in children is unavailable.\textsuperscript{128–132} The use of these blue dyes in enteral nutrition formulations has significantly decreased or been discontinued in many institutions due to reports of systemic absorption of the dye with the subsequent development of adverse outcomes.\textsuperscript{133}

PULMONARY FUNCTION TESTS IN INFANTS WITH DYSPHAGIA

Sequelae of pulmonary aspiration associated with dysphagia in children can include infections such as pneumonias and pulmonary abscesses. Other children can also develop chronic conditions such as bronchiectasis, pulmonary fibrosis, or bronchiolitis obliterans. When these conditions occur, they require treatment and monitoring. One of the monitoring tools now available in infants with dysphagia is pulmonary function tests (PFTs).

Recently, Tutor et al.\textsuperscript{134} performed (PFTs) in a group of 18 neurologically normal infants, born at term, each with a history of recurrent coughing and wheezing and who had dysphagia newly diagnosed using VFSS. Thirteen of the infants also had concomitant documented GER, and five of the infants were also exposed chronically to tobacco smoke. The PFTs were performed shortly after the diagnosis of dysphagia using the raised lung volume rapid thoracoabdominal compression technique\textsuperscript{135,136} and consisted of pre- and post-bronchodilator spirometry and measurement of lung volumes via plethysmography. Twelve infants had abnormal PFTs, with 11 demonstrating evidence of airways obstruction (AO), 4 of whom also demonstrated a component of bronchodilator responsiveness (BR) after receiving albuterol. Ten of the original 18 infants underwent a repeat PFT 6 months after initiation of therapies for dysphagia and GER. Of the 12 infants who had abnormalities on their initial PFTs, 3 infants continued to demonstrate AO without BR, and 2 infants continued to demonstrate AO with BR, respectively. One infant who initially demonstrated AO without BR on the first PFT demonstrated normal spirometry but a mild decrease in total lung capacity on plethysmography 6 months later. Two of the infants with AO on their initial PFTs had completely normal PFTs 6 months later. Eight of the 10 infants who performed PFTs initially and 6 months later, had documented evidence of GER. The initial PFTs of seven of those eight infants were abnormal but 6 months later four of the seven infants had normal PFTs. All five of the infants who were chronically exposed to tobacco smoke had abnormal initial PFTs but 6 months later, three of those infants had normal PFTs. The authors concluded that PFT abnormalities, predominantly AO, occur commonly in infants with respiratory symptoms who have been recently diagnosed with dysphagia and many of the infants continued to show abnormalities at follow-up.\textsuperscript{134} Performance of PFTs in infants diagnosed with dysphagia is suggested to determine if abnormalities are present. They may need to be repeated, particularly if the infants remain symptomatic despite appropriate treatment of their dysphagia.

TREATMENT OF DYSPHAGIA

Initial decisions for the treatment of dysphagia must take into account the prognosis for safe and adequate oral intake. The safest, most effective method of caloric intake may either be orally with compensatory strategies or temporary/permanent feeding tube placement.\textsuperscript{81,83} Compensatory strategies for infants and children may include changes in positioning, changes/modifications to utensils (including bottle/nipple systems), modifications to the viscosity of the liquids (thickening liquids), and targeting improved swallowing function through exercises and maneuvers that compensate for poor swallowing function or help improve it.\textsuperscript{81–83,86,137}

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Anecdotal reports suggest that use of thickeners for oral liquids may lead to adverse effects in certain populations of infants. Clarke and Robinson described the acute onset of ultimately fatal necrotizing enterocolitis (NEC) in two premature infants who received enteral feeds thickened with carob bean gum to relieve symptoms of GER. They suggested that the use of thickened feedings may have led to the onset of NEC. Recently, the US Food and Drug administration warned that the use of SimplyThick should be discontinued in hospitalized and recently discharged premature infants after 15 more infants developed NEC and 2 infants with dysphagia died after using this product to thicken their feedings. The risk of NEC may be related to the use of thickening products in general, especially those made with xanthan gum or other thickeners such as cornstarch. Caregivers may want to consider thickening liquid feedings with a more natural foodstuff, such as infant rice cereal, for premature infants with dysphagia. The gastrointestinal status must also be considered before making the decision to add rice cereal to the liquid feedings.

A potential new treatment for dysphagia in the pediatric population is the use of neuromuscular electrical stimulation to affect the cranial nerves. The stimulation causes the muscles involved in swallowing to contract, and this reportedly results in muscle strengthening or improved motor control. Humbert et al. reviewed the available published evidence regarding the effectiveness of neuromuscular electrical stimulation as a treatment for dysphagia. They concluded that it has a potentially positive effect on recovery from dysphagia, but they cautioned there is a paucity of available data, lack of agreement about the effects of it on swallowing function, and potential for harm with the use of this modality. Placement of the surface electrodes is critical, because results opposite to what is desired have been seen, such as the larynx descending versus ascending during the swallow. Other researchers have recently reported very little efficacy of neuromuscular electrical stimulation for treatment of dysphagia in children.

Surgical gastrostomy or jejunostomy tubes may be placed nasogastrically or nasojejunally but caregivers must be adequately trained in the proper insertion of nasogastric/nasojejunal tubes to prevent their migration into the lower airway with the resultant significant risk of iatrogenic aspiration pneumonia. This approach is generally used only for short-term treatment. These types of feeding methods are also used frequently in critically ill children, to try to reduce the risk of pulmonary aspiration. In a study involving 41 critically ill children who received transpyloric enteral feedings, none suffered from pulmonary aspiration and the incidence of pulmonary infection and hepatic dysfunction diminished during transpyloric enteral feedings. However, 10 of the children developed gastrointestinal complications consisting of abdominal distension, excessive gastric residual, and diarrhea. Gastrointestinal complications were more frequent in post-surgical than in nonsurgical patients. Subsequent reports indicate that the incidence of GER is increased in children during transpyloric feedings and in preterm infants, the incidence of gastrointestinal disturbances and mortality are increased in those who receive transpyloric feedings.

Surgical gastrostomy or jejunostomy tubes may be placed as an open procedure or by newer laparoscopic and percutaneous or endoscopic methods. Since it is more difficult to perform a fundoplication after a gastrostomy, many surgeons prefer to have an evaluation done to exclude GER before placement of a gastrostomy tube.

Multiple problems can occur after placement of a gastrostomy tube. The development of granulation tissue around the tube site was the most common problem sited in two studies occurring in 58% and 68% of patients, respectively, followed by tube dislodgement noted in 28% of patients in one of the studies. Also, the stoma may close quickly after the tube is accidently removed making reinsertion difficult if not impossible without surgical intervention. Other complications include new or deteriorating GER, infection, intra-abdominal leakage of feed, and gastrocolic fistulae.

Both major and minor problems can occur with placement of a feeding jejunostomy. In a report involving 89 patients who underwent placement of the jejunostomy, 15 patients (15.2%) had complications. Minor complications (7.2%) included dislodgement, blockage of the tube, and pericatheter leak. Major complications which required surgical intervention included detachment of the jejunostomy from the abdominal wall, leak into the peritoneal cavity, jejunal perforation by the catheter tip, and peritonitis after removal of the tube. Procedure related mortality was 3.2%. Also, if the tube is accidently removed, the stoma may close.

GASTROSTOMY/JEJUNOSTOMY TUBE PLACEMENT FOR SEVERE DYSPHAGIA

Children with dysphagia and chronic aspiration who continue to have recurrent significant respiratory symptoms despite the use of food modification, positioning, changes in flow-rate, and utensil use may ultimately need placement of a temporary or permanent feeding tube. This may become necessary acutely if there is inadequate intake of fluids or calories to prevent dehydration or malnutrition. The feeding tube can be placed nasogastrically or nasojejunally but caregivers must be adequately trained in the proper insertion of nasogastric/nasojejunal tubes to prevent their migration into the lower airway with the resultant significant risk of iatrogenic aspiration pneumonia. This approach is generally used only for short-term treatment. These types of feeding methods are also used frequently in critically ill children, to try to reduce the risk of pulmonary aspiration. In a study involving 41 critically ill children who received transpyloric enteral feedings, none suffered from pulmonary aspiration and the incidence of pulmonary infection and hepatic dysfunction diminished during transpyloric enteral feedings. However, 10 of the children developed gastrointestinal complications consisting of abdominal distension, excessive gastric residual, and diarrhea. Gastrointestinal complications were more frequent in post-surgical than in nonsurgical patients. Subsequent reports indicate that the incidence of GER is increased in children during transpyloric feedings and in preterm infants, the incidence of gastrointestinal disturbances and mortality are increased in those who receive transpyloric feedings.

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rapidly making tube reinsertion difficult, if not impossible, without surgical intervention.

The decision to place a feeding tube either on a temporary or permanent basis has long-reaching implications in the development of further feeding skills and the development of social, learning, and emotional skills.82–86

Several studies have been performed over the years regarding the benefit of having an antireflux procedure, such as fundoplication, at the time of placement of a gastrostomy tube, particularly in children with neurological impairment. Several studies have reported worsening or de novo development of GER after placement of a gastrostomy tube alone in 5–67% of these children. So far, this has not been predictable by studies such as pH probe monitoring, biopsy, or radiography. Thus, 5–34% of children will require anti-GER surgery, such as fundoplication, to control symptomatic GER.79,150–161

Fundoplications can be performed as a complete (360°) Nissen procedure where the fundus of the stomach is wrapped completely around the esophagus or a partial procedure, where the fundus is partially wrapped around the esophagus. Dysphagia, which can be a complication of fundoplication, has reportedly been more frequent after Nissen versus partial fundoplication in adults particularly adults with severe esophageal dysmotility disorders (scleroderma, post-myotomy achalasia).162 Partial fundoplication particularly the Toupet procedure (posterior 270° wrap of the fundus around the esophagus) or anterior fundoplication in adults, may more frequently come unwrapped leading to re-emergence of GER symptoms.162,163 However, in one report, 5% of Nissen fundoplications required surgical revision.163

Performance of a fundoplication can be associated with several serious intraoperative complications such as liver laceration, bowel perforation, bleeding, and peritonitis.164 Other complications include a “slipped” or disrupted fundoplication, dehiscence, hiatal hernia, and bowel obstruction.165 Post-operative development of dysphagia was noted to be significantly more severe after placement of a Nissen fundoplication when compared to placement of a Thal fundoplication in a group of 175 children.164 Frequent long-term problems have included gas bloating, dumping syndrome, esophageal dysmotility, achalasia, inability to vomit or burp, and slow eating.166 Despite placement of a fundoplication to reduce GER and placement of a surgical tube for feeding, some children with dysphagia will continue to have lower respiratory infections or other signs of aspiration. At that point, one needs to determine if salivary aspiration is occurring and if so, effective therapy needs to be provided.

Children who receive tube feedings have significantly more oral microflora that can be associated with aspiration pneumonia,167 and, they also have more dental plaque and calculus.168 Meticulous oral hygiene/care and more frequent visits to dentists are recommended for children who receive tube feedings.167,168 This type of care has been recommended for critically ill children to try to help decrease the incidence of ventilator-associated pneumonia.169 However, two recent studies did not demonstrate a decrease in the incidence of ventilator-associated pneumonia in critically ill children who received tooth brushing or oral hygiene care.170,171 In children with neurologic impairment and dysphagia, proper positioning of the head appears to prevent aspiration pneumonias.172

MANAGEMENT OF SALIVARY ASPIRATION

Oral anticholinergic agents, such as glycopyrrolate or scopolamine patches, have been used, especially in neurologically impaired children, to treat sialorrhea. Although effective in decreasing salivation, anticholinergic therapy can be associated with significant adverse side effects, including behavioral changes, constipation, dry mouth, thick secretions, urinary retention, constipation, flushing, nasal congestion, vomiting, diarrhea, and tachycardia. Treatment may need to be discontinued in up to one third of patients.79,173–176

In the last few years, several studies have shown that injections of botulinum toxin, particularly type A, are effective in controlling sialorrhea in children, particularly those with neurological impairment.177–181 The toxin is usually injected into the submandibular or parotid salivary glands with sonographic guidance up to four times per year. Up to 88% of the patients in one study showed a significant decrease in saliva production.177 Some researchers also reported a decrease in the numbers of hospitalizations and pulmonary infections after the injections, as well as, reduced pulmonary toilet requirements and reduced use of anticholinergic medication.178 The reduction in saliva production ranged from 6 to 28 weeks in one study.179 Reported complications have included self-limited oral bleeding, viscous saliva, parotitis, and transient xerostomia in a small number of patients.177,179,180 Berweck et al.181 reported a case study of a 15-year-old boy with cerebral palsy who, after three successful treatment sessions, developed antibodies to botulinum toxin type B, resulting in two subsequent treatment sessions with no clinical response. In some centers, the use of botulinum toxin has been discontinued due to migration of the toxin from the injection site resulting in paralysis of critical bulbar functions resulting in acute deterioration and death in children and adults, principally those with amyotrophic lateral sclerosis (ALS).182 Also, an adult with ALS developed recurrent jaw dislocation after intraparotid botulinum toxin injections for treatment of sialorrhea.183

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Surgical management of sialorrhea is an option in children for whom medical management fails. This often involves bilateral submandibular and parotid duct ligation or submandibular gland excision with parotid duct ligation. Recent studies have reported varying results, from up to an 87% success rate in controlling drooling to minimal control of sialorrhea with surgery.

Children who continue to aspirate and have recurrent pneumonias despite other medical/surgical therapies may need the placement of a tracheostomy, particularly one using a cuffed tracheostomy tube, for pulmonary toilet. Despite this, there is a lessened but still present risk of continued aspiration. There is the belief by some people that a cuffed tracheostomy tube has the potential of “tethering: the larynx which limits its elevation during swallowing and thus, negatively impacting swallowing safety.” As previously mentioned, the use of a tracheostomy speaking valve has been reported to reduce but not eliminate occurrences of aspiration, at least in adults. The valve allows movement of air during exhalation through the vocal cords so that adult or child with a tracheostomy can speak.

The definitive treatment for the elimination of chronic pulmonary aspiration is LTS or diversion. This procedure eliminates all continuity between the respiratory and digestive tracts by disconnecting the upper trachea from the larynx and diverting it directly to a stoma. The diversion of the proximal trachea to the esophagus allows for drainage of pooled secretions. With LTS, the proximal trachea is simply closed, and oral secretions that accumulate in the larynx are either orally expressed or swallowed. There is a loss of phonation, and the patient is left with a permanent tracheostomy. Two recent studies from Japan and one from Brazil documented the effectiveness of this procedure in children with intractable aspiration, particularly those who are neurologically impaired. However, complications can be considerable, such as tracheal granulations, bleeding, stenosis of the tracheal stoma, tracheomalacia, tracheal abscess, ruptured sutures, and tracheocutaneous fistula. Even if this procedure is performed without laryngectomy, LTS may not be reversible.

CONCLUSION

Due to new advances in technology such as FEES/FEESST, along with the current standard, VFSS, diagnosis of dysphagia, and pulmonary aspiration can now be made at an early age in children before significant morbidity has occurred. Other tests, such as the LLM index and use of colored dyes may be helpful in diagnosing aspiration in limited situations in certain select children. The salivagram is used to diagnose sialorrhea. Neuromuscular electrical stimulation therapy could possibly in the future be a complementary therapy for children with dysphagia along with the currently available feeding therapies or use of tube feedings. The use of botulinum toxin injections and resection of salivary glands are therapies along with the use of anticholinergic agents and tracheostomy and LTS procedures available to treat sialorrhea. Infant PFTs have documented that one of the sequelae of dysphagia and aspiration can be AO, which should be monitored in symptomatic infants. Hopefully, all these diagnostic and therapeutic modalities can help improve the prognosis for many children with dysphagia or aspiration and decrease subsequent morbidity and mortality.

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