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## *Continuing Education Questions*

**1. Which muscles demonstrate a dual respiratory and swallowing role?**

a. Mylohyoid
b. Sternohyoid
c. Omohyoid
d. a and b
e. b and c

**2. With respiratory distress, central respiratory activity takes precedent over central swallowing activity.**

a. True
b. False

**3. Straw drinking is associated with a high occurrence of the expiration prior to and after swallowing.**

a. True
b. False

**4. At the beginning of laryngeal elevation, what is the typical position of the glottis?**

a. Opened
b. Intermediate
c. Paramedian
d. Closed
e. None of the above

**5. The apneic pause, consistently recorded at the height of the pharyngeal swallow, is often terminated after the conclusion of pharyngeal swallowing activity and after final closure of the PES.**

a. True
b. False

# The Relationship Between Dysphagia With Aspiration and Respiratory Disease in Infants and Young Children

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The two primary functions of swallowing are to direct materials from the mouth to the stomach while keeping the airway protected and to provide the right types of liquids and foods to permit children to grow and develop normally and adults to stay healthy. Successful completion of these functions is dependent upon complex interactions between the deglutitory and respiratory systems. Significant disruptions in either system or in their coordination may result in a cascade of consequences. When dysphagia occurs in children with respiratory disease, it may further exacerbate pulmonary symptoms and result in nutritional compromise. Swallowing problems occur commonly in children with multiple underlying etiologies and, often, in medically fragile children (e.g., premature infants) where it may be just one component of a complex constellation of medical, health, and neurodevelopmental problems (Mercado-Deane et al., 2001; Newman, Keckley, Petersen, & Hamner, 2001). The purpose of this article is to review some of the factors contributing to the complex inter-relationships between swallowing dysfunction and respiration in infants and young children. Bronchopulmonary dysplasia (BPD), the most common form of chronic lung disease (CLD) in the pediatric population, will be discussed to illustrate some of these issues.

## *Consequences of Swallowing Dysfunction and Aspiration*

Occasional aspiration of small amounts of liquids or foods may be a relatively common or normal event; however, lung injury resulting from a single episode of massive pulmonary aspiration can result in significant morbidity and mortality in both children and adults (Warner, Warner, Warner, Warner, & Warner, 1999; Warner, Warner, & Weber, 1993). Some factors that influence respiratory outcomes following aspiration include the amount and type of material aspirated, the frequency of aspiration, and the host's response to aspiration (Terry & Fuller, 1989). For example, acidic aspiration tends to be more deleterious to the airways and lungs, than aspiration of a material with a more neutral pH (Agnew et al., 2002; Effros, Hogan, Wahlen, Olson, & Lin, 2001). Animal studies have demonstrated the development of fibrotic lung disease from acid instillation into the trachea (Popper, Juettner, & Pinter, 1986).

Children exhibiting oropharyngeal dysphagia with concomitant aspiration are likely to experience repeated insults to the airway. Our clinical experience suggests that some children with oropharyngeal dysphagia, characterized by aspiration, may also experience repeated bouts of indirect aspiration when gastroesophageal reflux (GER) is a problem. Consequently, these patients may be at increased risk for recurrent aspiration of acidic gastric contents in addition to liquids or food.

In animal models, recurrent aspiration of even small volumes can cause persistent inflammation, increased airway activity, and abnormalities in neural control (Colombo & Hallberg, 2000). In vulnerable in-

fants and children, it has been found to be a significant cause of morbidity, with complications including pneumonia, respiratory disease, and growth compromise or failure to thrive (Mercado-Deane et al., 2001; Newman et al., 2001; Radford, Stillwell, Blue, & Hertel, 1995).

While the impact of recurrent aspiration on the developing airway is not well understood, it has been suggested that many lung diseases in adulthood may originate from childhood lung disorders (Eber & Zach, 2001; von Mutius, 2001). Development of interstitial lung disease and fibrosis has been linked with chronic aspiration in children (Ahrens, Weimer, & Hofmann, 1999). As reviewed by Greenough (2000), children and adolescents with histories of prematurity, low birth weights, and CLD frequently exhibit recurrent respiratory problems and lung function abnormalities. Repeated aspiration can worsen underlying lung injury, particularly in children with underlying CLD or neurogenic dysphagia (e.g., cerebral palsy). In older children and adults with neurogenic dysphagia, respiratory distress and hypoxemia during mealtimes have been associated with aspiration events (Rogers, Arvedson, Buck, Smart, & Msall, 1994; Schatzlein, Ballantine, Thirunavukkarasu, Fitzgerald, & Grosfeld, 1979; St Cyr, Ferrara, Thompson, Johnson, & Foker, 1989). Currently available information, although limited, appears to suggest that failure to treat recurrent aspiration may adversely affect lung growth and, consequently, impair lung function in older children and adults. Furthermore, individuals with underlying lung disease in the setting of neurogenic dysphagia may be most vulnerable to the consequences of recurrent aspiration.

Unfortunately, there is no tool or algorithm to predict how well an individual is able to tolerate aspiration. In essence, we have no answer to the question, "How much aspiration is too much?" before a child develops respiratory consequences. Many factors can shift an individual's threshold of aspiration tolerance. Influences include, but are not limited to, the underlying diagnosis and prognosis; overall medical, health, and nutritional status; and the extent of the dysphagia. Ultimately, the impact of the dysfunction is determined by the balance between severity of the swallowing impairment and the child's compensatory mechanisms (Loughlin & Lefton-Greif, 1994).

The variability in clinical presentations associated with swallowing dysfunction and recurrent aspiration complicate evaluation and management efforts. Some children may present with chronic symptoms, such as pneumonia or persistent coughing. Others demonstrate episodic difficulties, such as coughing or increased congestion while feeding. Furthermore, responses to aspiration may differ according to age or the degree of maturity. Whereas younger infants may present with apnea or bradycardia, older children may cough or choke (Heuschkel et al., 2003; Thach, 2001). Another factor complicating the clinical identification of aspiration is that children may demonstrate similar respiratory presentations (e.g., wheezing or apnea), regardless of whether the response is triggered reflexively by vagally mediated receptors in the nasopharynx or larynx, or by direct aspiration.

It is well known that children with histories of younger gestational ages and low birth weights, neurogenic conditions, and congenital malformations of the upper aerodigestive tract are at increased risk for dysphagia. In fact, approximately 50% of children under one year of age who are valuated and diagnosed with swallowing dysfunction carry diagnoses of neurologic impairment or congenital syndromes (Mercado-Deane, Burton, & Harlow, 1998; Newman et al., 2001).

Although children with specific underlying etiologies are considered at high risk for dysphagia, clinicians need to be aware that other groups of children may also be at risk for chronic or transient dysphagia with concomitant aspiration. Recent studies have identified children with isolated neonatal dysphagia (Heuschkel et al., 2003; Sheikh et al., 2001). It has also been shown that previously asymptomatic infants may develop symptomatic swallowing dysfunction and aspiration following a viral infection (e.g., respiratory synctial virus [RSV]; Hernandez, Khoshoo, Thoppil, Edell, & Ross, 2002; Khoshoo, Ross, Kelly, Edell, & Brown, 2001; Khoshoo & Edell, 1999). Children with CLD, particularly those requiring supplemental oxygen therapy, are at greatest risk for severe responses to RSV. Therefore, it is reasonable to suspect that this group of children is at substantial risk for swallowing related difficulties following infection. Further research is needed to investigate the relationship between respiratory viruses and subsequent swallowing dysfunction.

## *Nutrition*

Swallowing dysfunction is often associated with poor nutrition, and the combination of poor nutrition and swallowing dysfunction may be particularly problematic in the pediatric population (Reilly, Skuse, Wolke, & Stevenson, 1999; Mathiesen, Skuse, Wolke, & Reilly, 1989). Malnutrition may be associated with impaired postnatal lung growth resulting in decreased lung function (Ong, Mehta, Ogston, & Mukhopadhyay, 1998; Sahebjami & Domino, 1992; Thomson et al., 1995). When associated with dysphagia, malnutrition may be particularly detrimental to lung development in infants with BPD, for whom optimal lung growth is essential for recovery. Nutritional

compromise has also been associated with increased mortality due to acute lower respiratory tract infections and it can interfere with a host's ability to recover from infections (Keusch, 2003; Yoon, Black, Moulton, & Becker, 1997).

Children with BPD are already at increased risk for nutritional compromise, because of increased work of breathing, hypoxia, and infections (Dumas et al., 1997). Wilson, McClure, Halliday, Reid, and Dodge (1991) reviewed a series of studies that provided evidence, by indirect calorimetry, of increased energy requirements in infants with BPD versus their controls.

Complicating the nutritional management of children with BPD are needs for fluid restriction and increased caloric intake and an increased risk of GER and other neurodevelopmental issues, including dysphagia involving any or all phases of swallowing. Dietary expertise is critical to the management of nutritional needs in this population. In addition, treatment of the underlying respiratory symptoms and GER may be helpful for some of these children. For example, supplemental oxygen, diuretics, anti-inflammatories, and bronchodilators can help reduce the work of breathing and relieve the degree of hyperinflation in children with BPD, thereby decreasing the risk of swallowing incoordination and nutritional compromise in this vulnerable group of children (Pandya & Kotecha, 2001; Jobe, 1999). Careful evaluation of feeding and swallowing function, including the use of appropriate instrumental procedures may identify the pathophysiology underlying oropharyngeal dysphagia and assist in the development of treatment plans to enhance nutritional status without contributing to further respiratory compromise.

## *Gastroesophageal Reflux*

Children with dysfunctional swallow may also have GER and those with CLD are at particularly high risk for GER for several reasons. First, the relative pressures between the chest and abdomen are altered by CLD. In patients with CLD, hyperinflation is common. Hyperinflation can cause lower intra-thoracic pressure relative to abdominal pressure, thereby creating a situation favoring the movement of gastric contents from the stomach up into the esophagus. In addition, coughing may increase intra-abdominal pressure, and "push" gastric contents from the stomach into the esophagus.

The relationship between GER and swallowing function remains unclear. Recently, Mendell and Logemann (2002) reported differences in some temporal measures during the pharyngeal phase of swallowing when comparing adults with GER with their controls without GER. Based upon their findings, these researchers speculated that changes in oropharyngeal motility may be an under recognized symptom of GER that warrants further investigation. Although comparable data in the pediatric population are lacking, it seems reasonable that infants and young children may be at risk for similar temporal variations in swallowing secondary to GER.

## *Cough and Airway Clearance Mechanisms*

The cough is the primary lower airway protective response after aspiration. The absence of a cough response following an aspiration event (silent aspiration) may predispose infants and children to lung injury. Silent aspiration is common in children with dysphagia with estimates ranging from 70-97% depending upon age and the underlying etiology of the dysphagia (Arvedson, Rogers, Buck, Smart, & Msall, 1994; Lefton-Greif et al., 2000; Newman et al., 2001; Sheikh et al., 2001). Although the reasons for the high incidence of silent aspiration in young children are unknown, one hypothesis is that silent aspiration may result from a blunting of airway defense mechanisms (e.g., cough; Loughlin & Lefton-Greif, 1994). A possible explanation for this blunting may be related to the maturation and transformation of laryngeal chemoreflex responses (LCRs), which are comprised of several airway protective reflexes. Thach (2001) suggested that some LCRs (e.g., rapid swallowing, laryngeal constriction, and apnea) emerge during fetal development as a protective mechanism against potential aspiration of amniotic fluid and that coughing may become a more important LCR during postnatal life (Thach, 2001). The hypothesis of LCR maturation may be consistent with observations of prolonged apnea, bradycardia, and rapid swallowing in preterm infants who have trouble coordinating breathing and swallowing. Their responses differ from normal adults who cough after aspirating. The natural history of the development of a cough in response to aspiration in children with and without dysphagia needs to be studied.

Silent aspiration is particularly problematic in children under 2 years of age because the protective cough mechanism is absent during the period of greatest lung growth (Thurlbeck, 1982). Furthermore, caregivers and clinicians may underestimate the presence of swallowing dysfunction in this population because silent aspiration, by definition, does not provide overt evidence of airway contamination.

## *Bronchopulmonary Dysplasia*

Bronchopulmonary dysplasia is the most common form of CLD in the pediatric population. The definition of BPD has changed since the condition was first reported by Northway, Rosan, and Porter (1967). Currently, the term BPD is used by many to refer to prolonged supplemental oxygen needs, usually beyond 36 weeks post-concep-

tual age (Greenough, 2000; Lemons et al., 2001). Estimates of the incidence of BPD in premature infants vary between 5-50% (Eber & Zach, 2001). It occurs most frequently in children with extreme prematurity and low birth weights (Fanaroff et al., 1995; Greenough, 2000). Exposure to hyperoxia, mechanical ventilation, and neonatal infections contribute to the development of BPD. Infants with BPD have fewer alveoli than age-matched controls (O'Brodovich & Mellins, 1985). Furthermore, the lungs of very low birth weight infants (<1500 grams) have been shown to exhibit growth arrest at very early stages of lung development, with characteristic findings of enlarged and fewer alveoli compared to controls (Jobe, 1999). Therefore, preterm infants with BPD are particularly vulnerable to any consequences associated with additional lung injury secondary to swallowing dysfunction with aspiration (Radford et al., 1995). In addition, recurrent aspiration may directly interfere with normal or compensatory lung growth through mechanisms of chronic inflammation and cell growth arrest (Jobe, 1999).

Two important issues for infants with BPD are to maximize physiologic "well-being" by avoiding respiratory distress (e.g., desaturation, pneumonia, increased work of breathing) and to promote adequate growth. In our experience, swallowing dysfunction may be one of the factors contributing to respiratory distress. Approximately 40% of the patients presenting to the Feeding and Swallowing Clinic at our institution have a history of prematurity, with more than 50% aspirating on the videofluoroscopic swallow study (VFSS), and silent aspiration occurring in 86% of those who aspirated (unpublished data). Swallowing dysfunction may cause aspiration or nutritional compromise. Limiting aspiration secondary to swallowing dysfunction is essential for the prevention of additional lung injury. Furthermore, pulmonary recovery is dependent upon adequate catch-up growth.

## *Evaluation and Management Considerations*

Clinicians must always evaluate feeding and swallowing function within the context of the "whole child." Additionally, a thorough evaluation and the development of a comprehensive management plan require input from multiple team members. Some specific considerations for speech-language pathologists working with infants and children with swallowing dysfunction and respiratory compromise are.

1. A focused history is critical for the evaluation and management of this population. The clinician needs to define the temporal relationship between feeding/swallowing dysfunction and the presenting respiratory symptoms. Some considerations include, but are not limited to, the child's age and the occurrence of any specific events (e.g., viral illnesses, surgery, changes in feeding routine) when problems first appeared; the relationship between the respiratory presentations and mealtimes (e.g., before, during, after feedings); and the time of day when problems are most prominent (e.g., all the time, only during meals, when sleeping). It is important to determine whether pulmonary symptoms are improving or worsening over time. Generally, children with BPD should exhibit marked improvement in pulmonary status during the first year of life. For example, the need for supplemental $O_2$ and respiratory medications should decrease with time. If not, ongoing swallowing dysfunction may be one of the factors interfering with the expected lung recovery. Likewise, children with BPD who do not show adequate catch-up growth may be failing to thrive because of poor swallowing function.
2. Speech-language pathologists should identify specific respiratory presentations (e.g., wheezing, stridor, congestion) and any environmental factors that may be contributing to respiratory problems (e.g., exposure to smoke or pets).
3. Appropriate instrumental assessments (e.g., VFSS) should be considered to define the swallowing physiology and to identify optimal feeding routine modifications for children with suspected oropharyngeal dysphagia. Thickened feedings are frequently prescribed for children with BPD and suspected swallowing dysfunction or GER. Although thickening of liquids has been helpful for some children, others have had problems, such has increased coughing, constipation, and delayed gastric emptying. Additionally, some infants and children with BPD may work "too hard" when drinking thicker liquids or may not be able to coordinate swallowing and breathing when nipple holes are enlarged to allow for bolus flow. Careful assessment is needed to determine whether thickened feedings or any other interventions are appropriate for an individual child.
4. Clinicians may need to answer questions regarding when and how to feed children with swallowing dysfunction and underlying respiratory diseases. To date, most clinical approaches are based upon experience rather than objective evidence. Clinicians need to be aware of the source of information for making these decisions and must work with other team members to make decisions about these medically fragile children.

The evaluation and management of children with swallowing dysfunction and underlying respira-

tory disease remains a challenge. Future research is needed to develop a better understanding of relationship among swallowing dysfunction, aspiration, and respiration in the pediatric population.

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## *Continuing Education Questions*

**1. Common symptoms of aspiration in young pre-term infants generally include all except**

a. apnea.
b. bradycardia.
c. cough.
d. rapid swallowing.
e. laryngeal constriction.

**2. Videofluoroscopic swallow studies may be indicated in infants and young children for suspected oropharyngeal dysphagia for the following reasons:**

a. To define the physiology of swallowing function
b. To identify modifications that may enhance the safety and efficiency of oral intake
c. To rule out aspiration
d. a and b.
e. all of the above

**3. In children with BPD, worsening lung function may be associated with**

a. aspiration.
b. nutritional compromise.
c. environmental exposures.
d. respiratory viruses.
e. all of the above.

**4. Children at high risk for swallowing dysfunction with aspiration include those with histories of**

a. malnutrition.
b. infants following acute RSV.
c. chronic lung disease.
d. neurodevelopmental delays.
e. all of the above.

**5. Recurrent aspiration may be associated with all the following except**

a. pneumonia.
b. poor catch-up growth.
c. hypoxemia.
d. maturation of a cough response.
e. poor lung growth.