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Impact of Aspiration in the Assessing Process of Pediatric Lung Disease

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Abstract
This study aimed at analyzing the impact of Aspiration in the assessing process of pediatric lung disease, as the affected children will frequently encounter a situation where swallowing is insecure and aspiration is likely. Besides analyzing the Aspiration of foreign matter into the airways and lungs that can cause a wide spectrum of pulmonary disorders with various presentations. And discussing the type of syndrome resulting from aspiration depends on the quantity and nature of the aspirated material, the chronicity, and the host responses. Considering that Aspiration is most likely to occur in subjects with a decreased level of consciousness, compromised airway defense mechanisms, dysphagia, gastroesophageal reflux, and recurrent vomiting.

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1.1 Introduction

All mammals have evolved sophisticated mechanisms to prevent aspiration of a foreign material into their lungs. The whale, for example, is particularly vulnerable with a constant passage of fast-flowing seawater across the pharynx and has developed a protective anatomy dedicated to control the flow away from the airway. In humans, there are protective mechanisms throughout the respiratory tract to deal swiftly with inevitable soilage (Wallis & Ryan, 2012).

The term *aspiration lung disease* describes several clinical syndromes. At one end of the spectrum is massive aspiration, usually of gastric contents, that causes acute symptoms and, occasionally, respiratory failure, whereas at the other end of the spectrum is chronic lung aspiration (CLA), which is repeated passage of food, gastric reflux, or saliva into the subglottic airways that causes chronic or recurrent respiratory symptoms (Boesch, Daines & Willging, 2006).

Normal physiology and anatomy dictate that although accidental aspiration occurs as part of normal life, the impact on the airways is limited. The foreign material is swiftly expelled, and any injury is rapidly repaired (Huxley, Viroslav, Gray & Pierce, 1978).

Aspiration of foreign matter into the airways and lungs can cause a wide spectrum of pulmonary disorders with various presentations. The type of syndrome resulting from aspiration depends on the quantity and nature of the aspirated material, the chronicity, and the host responses. Aspiration is most likely to occur in subjects with a decreased level of consciousness, compromised airway defense mechanisms, dysphagia, gastroesophageal reflux, and recurrent vomiting. These aspiration-related syndromes can be categorized into airway disorders, including vocal cord dysfunction, large airway obstruction with a foreign body, bronchiectasis, bronchoconstriction, and diffuse aspiration bronchiolitis, or parenchymal disorders, including aspiration pneumonitis, aspiration pneumonia, and exogenous lipoid pneumonia. In idiopathic pulmonary fibrosis, aspiration has been implicated in disease progression and acute exacerbation. Aspiration may increase the risk of bronchiolitis obliterans syndrome in patients who have undergone a lung transplant. Accumulating evidence suggests that a causative role for aspiration is often unsuspected in patients presenting with aspiration-related pulmonary diseases; thus, many cases go undiagnosed. Herein, we discuss the broadening spectrum of these pulmonary syndromes with a focus on presenting features and diagnostic aspects (Prather, Smith, Poletto, Tavora, Chung, Nallamshetty & Rojas, 2014).

1.2 Swallowing

Swallowing (*see figure 1*) as a function of delicate balance; shared functions and competing interests. The nasal, pharyngeal, laryngeal, and oral cavities have to provide us with 4 differing functions: breathing, swallowing, speech, and lubrication of the cavity's surfaces. At different ages, different functions require prioritization: the neonate must suckle milk from the breast while maintaining regular nasal breathing in a semi supine position; the toddler must cope with the formation of a food bolus from solid foods and swallow precise manageable portions while seated; the schoolchild must breathe through his/her nose and swallow secretions while dealing with upper respiratory tract infections during sleep; the adolescent must learn to speak garrulously and simultaneously eat voraciously with friends, yet remain monosyllabic and slouched when dining with immediate family. These competing and evolving demands of our aerophagic cavities make us uniquely vulnerable to aspiration as a species and enforced the development of sophisticated protective strategies (Richter, 2010).

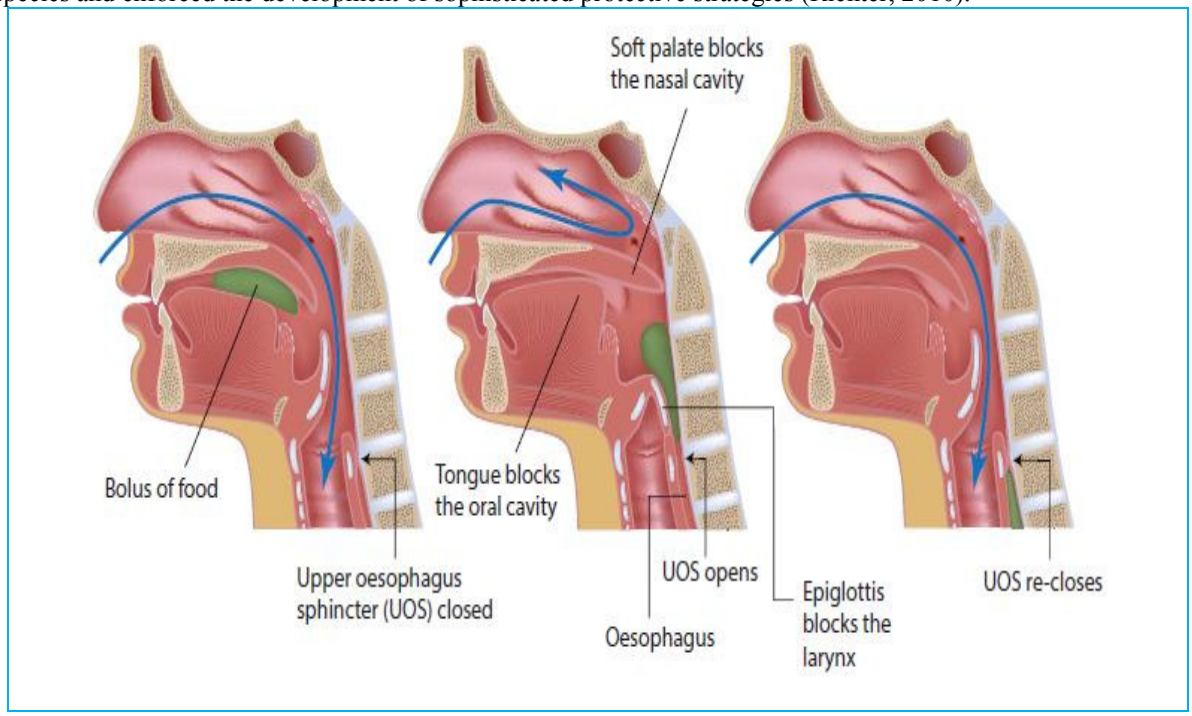

Figure (1): Swallowing anatomy

1.3 Acute lung aspiration

1.3.1 Assessment and Diagnosis

The diagnosis of acute aspiration is mainly clinical and usually involves witnessed inhalation of vomit or tracheal suctioning of gastric contents. Even in the absence of such events, however, a high suspicion index should be maintained when clinical and radiographic findings are compatible with aspiration. Early bronchoscopy may help to define the type of aspiration (ie, liquid versus particulate material) and improve clinical assessment (Campinos, Duvall & Couturier, 1983).

Clinical signs of acute aspiration include coughing, wheezing, chest discomfort, and fever. More dramatically, cyanosis, pulmonary edema, and rapid progression to severe respiratory distress syndrome may occur in cases of massive aspiration. Although high mortality was once reported with massive aspiration, recent studies estimated a mortality rate of 5% in children and no deaths when three or fewer lobes were involved (Hickling & Howard, 1988).

1.3.2 Management

Apart from immediate unblocking of airways in case of massive aspiration and general supportive care measures, further aspiration must be prevented. The benefits of artificial airway and oral or nasogastric tube placement should be weighed with caution against the increased risk for aspiration because of their effect on swallowing. Administering antacids or sucralfate to raise the stomach pH increases bacterial colonization in the stomach but not in the respiratory tract, and thus does not increase the risk for ventilator-associated pneumonia. The use of corticosteroids is controversial, with some studies proving efficacy, especially when given close to the time of massive aspiration, and others the opposite; given such uncertainty, their use is not generally recommended. Finally, there is some evidence that bronchoalveolar lavage (BAL) with normal saline and surfactant may have clinical value in treating severe aspiration syndrome in children (Marraro, Luchetti & Spada, 2007).

Should deterioration occur with some or all of these measures, infection ought to be suspected. Although it

does not usually play a primary role in aspiration of gastric contents, the rate of superimposed infection is high. Antibiotics should be withheld unless there are reasonably clear signs of infection. Antibiotic therapy should be selected on the basis of aspiration pneumonia bacteriology, which mainly depends on the presence or absence of preexisting disease, the patient's age, and prior use of antibiotics.

1.4 Chronic lung aspiration

Small-volume aspiration into the lungs is relatively common, even in healthy subjects when normal airway protective mechanisms are impaired, bypassed, or overwhelmed. Whether intermittent or persistent, CLA may occur in some children only coincidentally with other stressors, such as upper respiratory tract infection.

CLA may present with chronic cough, wheeze, noisy breathing, choking during feeding, recurrent episodes of pneumonia or bronchitis, and failure to thrive. Chronic aspiration often results in progressive lung disease, bronchiectasis, and respiratory failure and is a major cause of death in children with severe neurologic disorders. There is no “gold standard” test for diagnosing CLA, and determining whether aspiration is a significant cause of respiratory disease remains a challenge in pediatric medicine (Goyal, Jones & Couriel, 2006).

1.4.1 Aspiration attributable to swallowing dysfunction

Normal swallowing, a complex process requiring coordinated voluntary and involuntary actions, involves the mouth, pharynx, larynx, and esophagus in different phases. The maturation of oral and pharyngeal anatomy and the evolution of the suckling process develop parallel to the development of the brain and the nervous system. Anatomic abnormalities and intrinsic dysfunction in the effectiveness, duration, or timing of any of these components can result in direct aspiration.

Although children with neurologic disease are at high risk for aspiration, the inability to coordinate swallowing can be a problem in normal infants, especially those born prematurely. In such cases, cricopharyngeal incoordination is attributable to delayed maturation of swallowing reflexes; it has been suggested that it appears more frequently in young infants with bronchiolitis. A recent retrospective study in children with documented swallowing dysfunction showed that multisystem involvement (ie, medical conditions affecting more than one organ system) was highly associated with aspiration pneumonia (Weir, McMahon & Barry, 2007).

1.4.2 Reflux aspiration

An association between GOR and respiratory symptoms is well documented, but a causal relation is difficult to determine in an individual child. Possible mechanisms involved in this relation are listed in Box 1. In a study evaluating the relation between aspiration and recurrent respiratory tract infections in children with neurologic disability, Morton and colleagues found that oral and pharyngeal motor problems were the major cause of respiratory involvement and that GOR without a coexisting swallowing dysfunction was less likely to cause respiratory tract infection. Despite these findings emphasizing the role of swallowing dysfunction in children with neurologic disability, patients with GOR have significantly reduced laryngopharyngeal sensitivity because of repeated exposure of mucosa to small amounts of acid; this could potentially result in an increased risk for aspiration (Phua, McGarvey & Ngu, 2004).

1.4.3 Salivary aspiration

Chronic saliva aspiration is the least commonly recognized form of aspiration and is usually not diagnosed before development of significant lung injury. The oral cavity contains potentially pathogenic organisms that, when aspirated in sufficient quantity, can cause recurrent pneumonia or pulmonary abscess. Most neurologically impaired children who aspirate saliva do so because of severe swallowing incoordination and reduced laryngopharyngeal sensitivity rather than excessive production of saliva (Hussein, Kershaw & Tahmassebi, 1998).

1.5 The Lungs’ Defensive Strategies against Aspiration

Throughout the normal pediatric respiratory tract, from the tip of the nose to the alveoli, there are defensive layers to prevent the aspiration of the foreign material and expel unwanted transgressors that bypass the systems.

- Nasal turbinates generate turbulent flow and enforce impaction on the mucous membranes.
- Sneezing and coughing are forceful physiological expellants.
- Mechanoreceptors and chemoreceptors are concentrated over the surface of the pharynx, epiglottis, arytenoid cartilages, and vocal cords.
- Chemoreceptors are stimulated by water, salts, sugars, and acids penetrating the larynx and can trigger a chemoreceptor reflex, held responsible for reflex apneas and apparent life-threatening events in neonates.
- A highly sophisticated muco-cilliary system contains 3 important components: a fluid layer of precise volume and tonicity; beating cilia; and a covering layer of mucus— precise in its elasticity, viscosity, cohesion, and adherence.
- Epiglottic closure provides the trapdoor protection to the larynx during some (but not all) phases of

swallowing.
- Adduction of the true and false cords adds a further layer of structural defense.
- Bonchospasm (along with cough and apnea) may also be a defensive mechanism, narrowing the airway's lumen against a potential noxious influx—even before penetration through the larynx. The commonality of the vagus nerve system serving both the lower esophageal junction and the airway smooth muscle is a suggested mechanism.
- The alveolar macrophage-scavenging system mops up the final perpetrators at an alveolar and bronchiolar level (Praud, 2010).

1.6 Children at Risk of Recurrent Aspiration

There is no single satisfactory classification of the causes of aspiration. Etiology varies for differing age groups and is best grouped loosely into the following categories:

1.6.1 Structurally normal children

Premature infants would fall into this category requiring tube feeding until maturation of the swallowing mechanism. Similarly, the neonates with severe respiratory syncitial virus (RSV) infection and tachypnea may temporarily lose their ability to protect their airways. Gastroesophageal reflux (GER) or esophageal dysmotility can also result in aspiration in otherwise structurally normal children confused by the sudden appearance of gastroesophageal contents in the pharynx (Ravelli, Panarotto, Verdoni, Consolati & Bolognini, 2006).

Oropharyngeal dysphagia can also occur in infants without any detectable risk factors who present with unexplained respiratory problems. This may represent some form of delay in the maturity of their swallowing integrity. The prognosis for resolution in these children is good, although it can take years (Lefton-Greif, Carroll & Loughlin, 2006).

1.6.2 Congenital abnormalities of craniofacial and upper airway structures

Aspiration during swallowing can be common in congenital anatomical variants such as craniofacial syndromes, Pierre Robin sequence, and laryngeal clefts or vocal cord palsy (Monasterio, Molina, Berlanga, Lopez, Ahumada & Takenaga, 2004).

1.6.3 Children with neurological abnormalities and disorders of swallowing strength and coordination

Feeding problems are common in children with neuromotor impairments. In a community-based survey, oral motor dysfunction was demonstrated in more than 90% of a sample of 49 children with cerebral palsy19 and evidence of chronic aspiration in 41% in a separate community study. Swallow function in children with Down syndrome is commonly abnormal. Children with spinal muscular atrophy and Duchenne muscular dystrophy eventually develop dysphagia with aspiration. Children with cerebral palsy, familial dysautonomia, and neuromuscular disorders may aspirate due to combined swallow dysfunction and GER.(Bach, 2007).

1.6.4 Iatrogenic interference

Long-term intubation and ventilation can impact on swallowing integrity and interfere with feeding for some time after extubation. Tracheal surgery and a tracheostomy tube may hinder the subglottic rise in tracheal pressure and necessary elevation of the larynx during swallowing. However, there is an ongoing conflict in the literature regarding the impact of long-term tracheostomy, with or without mechanical ventilation, and swallow function. Current thinking inclines to the view that the need for a tracheostomy, rather than the presence of the tube itself, indicates an underlying pathology (eg, respiratory failure, trauma, CHARGE syndrome) that could already predispose to aspiration risk (Leder, Baker & Goodman, 2010).

1.7 Classification of Pediatric Aspiration

1.7.1 Over-the-top aspiration

Aspiration over the top refers to the cause of the aspiration event occurring during the swallowing process. This includes the aspiration of nasal or sinus secretions, oropharyngeal contents, swallowed liquids, purees, and solids, and accidental foreign body aspiration due to a wide range of abnormalities as listed. Children with structurally normal upper airways, those with congenital abnormalities, and those with neurological conditions are all at risk via this mechanism.

1.7.2 Aspiration through the middle

The commonest of these malformations is tracheoesophageal fistula (TEF). A TEF may be congenital, that is, H-type TEF, or more rarely secondary.

1.7.3 Aspiration from below: gastroesophageal reflux disease

Although this review is principally looking at the consequences of aspiration over the top, it would be remised not to briefly consider the impact of GER and the lung—part of the spectrum of gastroesophageal reflux disease. The prevalence appears very high in most pediatric practices, although it remains extraordinarily hard to prove.10 The very complex and controversial area of the interrelationship between pediatric lung and airway conditions is beyond the scope of this article.

1.8 Diagnosing Aspiration

1.8.1 Clinical assessment

The history and clinical features of pulmonary aspiration are variables ranging from clear choking episodes to entirely silent events with no evidence even on careful history, clinical examination, or swallowing evaluation by an experienced therapist. Estimates of silent aspiration in children with severe cerebral palsy and dysphagia undergoing video fluoroscopy range from 31% to 97%. The history, examination, and swallow assessment need to be tailored toward the age of the child. Some features are common across all pediatric ages, and others are age specific.

1.8.2 Radiological imaging

A plain chest X-ray is traditionally the first radiological investigation for suspected aspiration. It is useful to detect acute areas of collapse or over inflation and will also demonstrate chronic changes such as bronchial wall thickening and established bronchiectasis. However, it is not a sensitive tool for early or subtle changes. The current principle behind the investigation and management of aspiration in children is to assess and act at the earliest signs of aspiration lung damage, and from this perspective, the plain chest film contributes little. High-resolution computed tomography (CT) imaging plays an increasing role in the detection of early-airway and parenchymal changes in children who aspirate. The findings of aspiration on a high-resolution CT scan include areas of hyperinflation and ground-glass opacity (mosaicism), frank bronchiectasis, the tree-in-bud appearance of small-airway thickening, and the rarer finding of interstitial changes. None of these changes are specific for aspiration, but a characteristic distribution to the basilar and apical segments of the lower lobes in a clinical setting that favors aspiration makes the CT scan a useful supportive diagnostic tool. Unfortunately, the radiation exposure limits its use as a method for repeated monitoring. A recent study of CT scans in children with laryngeal clefts revealed changes in all 67 pediatric patients. Although the lower lobes were more frequently involved, no area was spared, and there was a range of radiological changes, although consolidation and reticular opacities predominated.

1.9 Strategies to Limit Aspiration and Prevent Lung Damage

Notwithstanding the limitations on attempting to prove and quantify aspiration, in much of the literature, and indeed in clinical practice, a linear relationship between the severity of oropharyngeal aspiration and the development of pulmonary consequences is assumed. There is minimal evidence, however, to support this belief, and thus to determine an action or intervention threshold as to when a child is safe versus unsafe to feed orally.80 Strategies to limit aspiration and prevent lung damage remain the cornerstone of individual feeding regimens and will usually incorporate the following considerations:

1.9.1 Altering consistencies and posture

A well-executed video fluoroscopy study not only provides evidence for aspiration but will also explore relative risks for different consistencies of feed and optimal posture during feeding. Advice regarding volumes, cups, spoons, bottles and teats, posture, thickeners, and consistency can significantly improve the aspiration risk and consequent lung health.

1.9.2 Non-oral feeding

For some children, the swallow control is too unreliable to provide sufficient calories safely via an oral route. The move to non-oral feeding will almost always involve careful discussion with the families. Feeding one's child is a strong and primitive need, and for some parents (and grandmothers), the move to gastrostomy feeds is a cause for considerable family distress.

1.9.3 Secretion control

Notwithstanding successful interventions to remove the aspiration risk by moving to non-oral feeding, some children have repeated respiratory sequelae from salivary aspiration. The use of agents to dry secretions can be helpful. The scopolamine patch is often advocated, but can be difficult to use, as it can provide an erratic drying response, especially if the patch is cut to try and limit the dose delivered, but results in unpredictable leeching of the drug through the cut edge. Oral anticholinergic agents such as glycopyrrolate or hydroxyzine at have the advantage of more frequent dosing and titration of effect, but can produce troubling side effects such as constipation, dry mouth, thick secretions, and tachycardia.

Conclusion

Pediatricians caring for neuro-developmentally affected children will frequently encounter a situation where swallowing is insecure and aspiration is likely, but the family remains very reluctant to consider non-oral feeding. For many of these children, feeding is their only pleasure, and from the family's perspective, the child's participation in family mealtimes is crucial to their psychosocial wellbeing. For parents, a gastrostomy may be seen as yet another step in pathologizing their child. Parents and professionals may be thrown into a confrontational situation where there is disagreement about which course of action is in the best interests of the child. Compromise positions need to be sought, but this leads to some imponderable questions: What is the

definition of unsafe to feed, and how do we evaluate the harm accruing from oral feeding.

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