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Review Article

Evaluation of Pediatric Subjects with Swallowing Disorder Part II

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The characteristics of pediatric swallowing, anatomical differences between pediatrics and adults, and swallowing problems in common pediatric diseases had been introduced in Part 1 of the article. The common methods for evaluation of pediatric swallowing are discussed in this part. The evaluation of swallowing function in pediatric patients is a great clinical challenge. It requires a team approach, an integration of multiple disciplines, and instrumental evaluations for establishing a diagnosis and developing an appropriate management plan. This article provides an introduction of the vital concept of clinical bedside evaluation and instrumental evaluation including the videofluoroscopic swallow study (VFSS), fibroptic endoscopic evaluations of swallowing (FEES), oximetry, and ultrasonography. The clinical applications, advantages, and limitations of these techniques are discussed. The imaging techniques and related anatomy of ultrasonographic evaluation of swallowing have been described in detail. Ultrasonography is an ideal tool for observing the soft tissues including the tongue and mouth floor muscles, and it has been implemented in assessing the suckling movements of infants. More research is needed to define the role of ultrasonography in evaluating the swallowing function in pediatric patients. (Tw J Phys Med Rehabil 2013; 41(3): 163 - 171)

Key Words: deglutition disorders, pediatrics, ultrasonography

INTRODUCTION

The prevalence of feeding disorders in the pediatric population ranges from 25% to 45% in typically developing children and from 33% to 80% in children with developmental disorders.[3-5] Approximately 37% to 40% of infants and children assessed for feeding/swallowing problems were born prematurely;[3-6] premature infants are at an increased risk for respiratory, neurologic, and

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developmental problems. The other risk factors for feeding disorders include craniofacial anomalies, cardiorespiratory deficits, airway problems that may require surgery (e.g., tracheostomy), and gastrointestinal deficits (e.g., tracheoesophageal fistula, eosinophilic esophagitis, and motility problems).[8]

Despite the recent proliferation of research about adult swallowing disorders, there has been limited research on the evaluation of infant swallowing. Furthermore, the parameters that define adult swallowing and dysphagia cannot always be applied to infants because of the differences in the relationship of anatomic structures and the lack of neurologic maturation.[9] Moreover, the regular instrumental evaluations to assess the swallowing function, such as videofluoroscopic swallowing study (VFSS), fiberoptic endoscopic evaluation of swallowing (FEES), or manometry, are not always suitable for evaluating infants because of their invasive nature and the need for adequate cooperation. Ultrasonography has been used in the evaluation of the swallowing function in adults in several aspects. It could be a potential tool to assess the swallowing function in infants and children.

ASSESSMENT OF INFANTS AND CHILDREN SUSPECTED OF HAVING DYSPHAGIA:

General Concept

Early evaluation of swallowing dysfunction and the prompt initiation of appropriate therapies are critical to temper the impact of morbidities associated with dysphagia.[7] The integration of multiple medical, health, and developmental disciplines is essential for establishing a diagnosis and developing an appropriate treatment plan for pediatric patients with feeding/swallowing problems. A team approach provides a mechanism for the coordination of multiple evaluations, the compilation of findings, and the determination of a comprehensive patient management plan. The team approach also provides consistency in the communications given to caregivers, family members, and the patient regarding the plan of care.[1] Additional evaluations by specific disciplines may demonstrate the need for further assessment of the structural integrity of the upper aerodigestive tract, the patient's airway protection mechanism, the pharyngeal and esophageal motility, and the hypopharyngeal sensation. Multiple diagnostic tests, such as VFSS, FEES, ultrasonography, and manometry, are subsequently used.[1]

The evaluation of infants and children with feeding problems is different from that of adults with dysphagia in several ways. The anatomy and physiology of these two populations are distinctly different; the feeding and swallowing function changes dynamically as a child grows. The infant or child may be unable to state that he/she is having trouble swallowing. Dysphagia may not be diagnosed until it compromises respiratory function or normal growth or until the child exhibits negative behaviors when feeding. The infant or child may not be able to describe the specific difficulty experienced during feeding; this information often comes through the observations of a caregiver. There is more often a relationship between the symptoms in the esophageal and oropharyngeal phases in children compared with that in adults. There is also a more direct relationship between the body posture/tone, the abilty to move, and the ability to eat and swallow in children compared with that in adults[17].

Clinical Bedside Evaluation

The evaluation of children with feeding/swallowing difficulties begins with a thorough history taking and physical examination. The clinical examination should be organized, symptom-specific, and directed with an effort to identify the appropriate diagnostic tests to determine the nature and extent of the swallowing impairment. This process is often complicated by the variable presentations in feeding/swallowing disorders in children.[7] The evaluation begins with a focused feeding history, including current diet, feeding times, feeding amount and frequency, routes of administration, dietary modifications, and feeding positions. A history of recurrent pneumonia may indicate chronic aspiration; a history of stridor related to feeding may indicate a glottic or subglottic abnormality. The presence of snoring may suggest tonsillar and adenoid hypertrophy. Nutritional and psychologic assessments should be undertaken early in the evaluation process; psychologic assessments help to identify behavioral and parental factors that may contribute to a feeding disorder. It is important to assess whether the caloric intake meets the metabolic needs of the child because

many patients with swallowing disorders have concurrent illnesses that may increase metabolic needs. Specific food aversions may also provide clues regarding any underlying metabolic or allergic disorders.[16] Anatomic or functional disorders that make feeding difficult or uncomfortable for the child may also result in a learned aversion to eating, even after the underlying disorder is corrected. Furthermore, delays in the initiation of feeding caused by the underlying disorders may affect the normal acquisition of feeding skills.[16]

The physical examination begins with the clinicians observing a feeding session. The neuromuscular tone, posture and position during feeding, patient motivation, oral structure and function, and efficiency of oral intake are important factors that affect feeding. Important observations include the ability to handle oral secretions, the pace of feeding, the occurrence of leakage of food from the mouth, the movements of tongue and jaw, the ability to achieve and sustain airway protection during oral intake, the number of swallows to clear a bolus, noisy airway sounds after swallowing, the coordination of suck and swallow, laryngeal elevation, and gagging, coughing, or emesis associated with feeding. Attention to articulation and voice quality also may provide useful information because the structures used for the oropharyngeal phases of feeding and those needed for speech production are closely related[17, 18]. The absence of obvious signs of a swallow dysfunction does not rule out a swallowing disorder, particularly in a child with a history of recurrent pulmonary disease, in whom silent aspiration may occur. Oral cavity anatomic abnormalities, such as ankyloglossia, cleft lip or palate, or macroglossia, need to be excluded. A careful developmental, medical, and feeding history as well as physical examination usually provides clues to the tentative diagnosis that guides the selection of further diagnostic tests.[16]

Instrumental Evaluation

An instrumental evaluation is recommended when there is an uncertainty in the clinical findings, or when the clinical evaluation identifies problems that may reflect conditions that are not visible. Instrumental evaluations are conducted in an attempt to understand the nature and pathophysiology of the dysphagia and to obtain the information needed to develop appropriate management plans. VFSS and FEES are the most common instrumental evaluations recommended for the assessment of oropharyngeal dysphagia in infants and children.[7] VFSS has been considered as the gold standard method for swallowing assessment. Diagnostic ultrasonography provides real-time 2D images of the oropharyngeal structures and may provide quantifiable images of many of the structures related to the oropharyngeal stage of swallowing;[23] this technique could be a potential tool in the near future. Oximetry is used to monitor the occurrence of aspiration during feeding, but cannot define the pathology in the swallowing process.

Videofluoroscopic Swallow Study

VFSS provides direct, quantifiable information on the movements of the tongue, hyoid bone, posterior pharynx, larynx, and esophageal sphincters simultaneously. It is considered the standard for the assessment of oropharyngeal swallowing in adults.[23] In pediatric dysphagia, the liquid barium can be mixed with formula, breast milk, or pureed foods; barium paste can also be spread on crackers, which allows the evaluation of all food textures. If desired, liquids can be modified into different consistencies. The infant is typically fed by bottle or spoon, but in some cases, small amounts of barium are introduced by syringe followed by the sucking of a pacifier.[18] The advantages and limitations of VFSS are listed in Table 1[18].

Fiberoptic Endoscopic Evaluation of Swallowing

The indications for using FEES and FEES plus sensory testing (FEES-ST) in the pediatric population are the same as in adults.[7] FEES does not provide information regarding the oral phase of swallowing but compares favorably with VFSS for the evaluation of the pharyngeal phase. FEES can be augmented with a new approach that measures sensation in the pharynx using a special scope that administers a calibrated puff of air onto the arytenoids or epiglottis. The ability to initiate airway closure with stimulation indicates intact airway protection. FEES and sensory testing may be particularly valuable for the evaluation of swallowing safety in children who refuse to ingest adequate amounts of barium for VFSS. In such cases, studying the anatomy and evaluating the patient's

ability to handle oral secretions provide useful information. Table 2 provides a description of advantages and disadvantages of the FEES. Although there are clinical reports that FEES is commonly used to assess swallowing function in young children, other reports indicate that children under 6– 8 years of age do not tolerate the FEES procedures[16, 22]. Flexible endoscopy is not a substitute for rigid endoscopy in the evaluation of laryngeal anatomy; laryngeal clefts can be overlooked during examination by flexible endoscopy.[16]

Oximetry

Oximetry detects the oxygen saturation of capillary blood flow through an external sensor. Under most circumstances, the normal infant has an oxygen saturation above 95%. Oximetry levels below 90% generally indicate some degree of hypoxia. While baseline oximetry levels may be lower for premature infants, levels below 90% are usually undesirable parameters in this group.[25]

Oximetry can be used to monitor an infant's baseline oxygen saturation, changes in the oxygen saturation in response to handling or work (such as that involved in feeding), and the effectiveness of oxygen therapy. It is worth noting that normal values do not necessarily indicate safe feeding if cyanosis occurs secondary to a drop in oxygen saturation.[18] Pulse oximetry has a number of advantages, including noninvasiveness, no exposure to radiation, and minimal patient cooperation; this can provide quantitative measurement and continuous monitoring during a meal. However, the accuracy of pulse oximetry for detecting aspiration is still debatable. Some studies have reported a predictive rate of up to 80% for aspiration[10,11], but others have questioned the correlation between the desaturation measured by oximetry and the aspiration noted during VFSS.[12,13,14] In general, oximetry is still a useful adjunct tool in assessing the swallowing function during meals.

Table 1. Advantages and limitations of the videofluoroscopic swallowing study [18]

Advantages	Limitations
Real-time record	Does not identify structural problems of the esophagus
Simulates eating experience	Small sample of feeding
Ability to try various textures	
Ability to evaluate treatment techniques	
Good detail of the swallowing function	

Table 2. Advantages and disadvantages of the fiberoptic endoscopic evaluation of swallowing[16,22]

Advantages	Disadvantages
Relatively inexpensive and portable	Does not assess the oral or esophageal stages of swallowing
Provides detailed information about pharyngeal and laryngeal structures	To tolerate the transnasal tube placement, local anesthesia is sometimes required
It does not require the administration of food; useful in assessing the patient's swallowing ability as well as the structures/function of swallowing before food is introduced	Invasive and may interfere with swallowing in some patients
	It does not comprehensively assess swallowing physiology
Can be used to assess children with suspected vocal fold dysfunction or laryngotracheal abnormalities	
No radiation exposure or ingestion of barium	Although there are clinical reports that FEES is commonly used to assess swallowing function in young children, other reports indicate that children under 6– 8 years of age do not tolerate the FEES procedures
It assists in assessing neurologic status and ssensation	
It can be used to provide biofeedback as a part of swallowing therapy	

ULTRASONOGRAPHIC EVALUATION

Ultrasonography has been used to evaluate the swallowing process of adults since the late 1970s, although no conclusive results have been drawn.[1-6] Previous studies have focused mainly on the evaluation of tongue motion by ultrasonography.[15,19] Decreased tongue movement in the patients with dysphagia has been shown by ultrasonography in previous studies.[1,4,5] Kuhl et al. first applied ultrasonography to analyze the larynx elevation in subjects with dysphagia and concluded that ultrasonography seemed to be an ideal tool in the evaluation of swallowing function.[20] Subsequently, ultrasonography has been used in assessing larynx elevation and hyoid bone displacement.[7,21,24] These studies suggested that ultrasonography could have a potential role in evaluation of the swallowing function both in tongue and laryngeal movement (Table 3) [22]. Although limited research had focused on its application in pediatric population, it seems that ultrasonography could be a possible tool in the evaluation of the suckling of infant/children. [29,30]

NORMAL ULTRASOUND ANATOMY[25]

The Mouth Floor

During ultrasonography, the major oral soft tissues are visible from a midline sagittal position. The muscles and fascial boundaries of the tongue and the mouth floor (genioglossus, geniohyoid, and mylohyoid) can be seen. The transducer was angled 15° posteriorly to visualize the hyoid bone and upper pharynx. Because ultrasound beams cannot penetrate bone, the hyoid bone can be localized by finding the echogenic area with an acoustic shadow at the site of the insertion of the geniohyoid and mylohyoid muscles. The mylohyoid and geniohyoids are best seen in coronal sections. In this view the mandibular bone casts slightly curved, acoustic shadows on both sides of the tongue musculature.

Table 3. Advantages and disadvantages of ultrasonography[22]

Advantages	Disadvantages
The patient can be evaluated in an upright position, lying down, or sitting on a lap	Cannot directly determine whether aspiration has occurred: the imaging field is not broad enough to view the mouth, pharynx, and esophagus simultaneously
Images are collected in multiple planes in real time. Images can be digitized and enlarged for further examination of fine details, or stored on videotape for dynamic analysis	Ultrasound will not pass through the bone. Soft areas behind the larynx, mandible, and hyoid cannot be imaged
Barium is not required: any amount, type of texture of solid or liquid food can be imaged during swallowing	Quality of images and interpretation depend on the operator
Noninvasive and no radiation exposure; can be used repeatedly and for prolonged periods of time	
Can evaluate the effects of oral sensory motor stimulation techniques and study the sucking patterns of preterm infants	
Typically used to assess the oral preparatory and oropharyngeal stages of swallowing	
Portable	
Good for studying children with cerebral palsy or poor feeders who require frequent monitoring of the oral preparation and oral stages of deglutition	

The Tongue

The surface of the tongue and the lingual mucosa appears as a broad, curved white line in the midline sagittal view. Normal lingual anatomy can be viewed from the coronal plane by turning the transducer 90° from sagittal position. The tongue has a mushroom-shaped appearance, with the triangular genioglossus muscle in the center. The intermuscular septum inferiorly separates the tongue from the geniohyoid, mylohyoid, and anterior digastric muscles of the mouth floor.

IMAGING APPLICATIONS

The Mouth Floor

The mandible and the hyoid bone are two anatomic landmarks in the mid-sagittal view of the mouth floor. Sonographically, they present as echogenic areas with posterior acoustic shadowing.[26] The most superficial muscle layer of the submental region is the platysma. The mouth floor mainly consists of three muscles: the digastric, mylohyoid, and geniohyoid muscles.[27] The anterior belly of the digastric muscle originates from the digastric fossa and runs superficially to the mylohyoid muscle and is attached to the hyoid bone by a fibrous sling. The posterior belly inserts at the mastoid process.[26] The mylohyoid and geniohyoid muscles start from the posterior surface of the mandible and end on the hyoid bone. The mylohyoid muscle is a thin layer that connects the bilateral mandibular branches in a U- or V-shape and is fixed on the hyoid bone at the proximal end. It is called the “oral diaphragm.” The right and the left parts are connected in the midline by a raphe.

Sonographically, the mylohyoid muscle appears as a hypoechoic convex layer. The geniohyoid muscle extends from the geniohyoid tubercle to the hyoid. The genioglossus and hypoglossus muscles are best seen in sagittal scans. The genioglossus muscle lies on the geniohyoid muscle and inserts into the tongue in a fan-like shape. The hypoglossus muscle lies posteriorly and extends from the hyoid bone laterally into the tongue.[26]

The Tongue

The tongue rests on the muscles of the mouth floor. The extrinsic tongue muscles originate from the bony skeleton. The intrinsic tongue muscles originate and insert within the tongue itself. The muscles have free ends in the lingual aponeuroses. The superficial longitudinal muscle curves below the mucosa from the tip of the tongue to the hyoid bone; the deep longitudinal muscle extends between the genioglossus and hyoglossus muscle from the tip to the base. The transverse muscle of the tongue is located between the superficial and the deep longitudinal muscles and courses from the lingual septum to the lateral border of the tongue. The tongue muscles are more homogeneous and echogenic sonographically than the muscles of the mouth floor. Sonomorphologic differentiation of the intrinsic tongue muscles is not possible. The lingual septum appears as an echogenic line; the mucosal surface of the tongue is also demonstrated sonographically as an echogenic line. When the tongue tip protrudes beyond the mandible, it becomes invisible because of the acoustic shadow of the mandible.[26]

Ultrasonography of Sucking

Ultrasound imaging is both noninvasive and flexible in its approach. Most recently, techniques have been developed to investigate swallowing of the fetus in utero, infants, and young children.[29,30] Optimal positioning and attachment of the infant to the breast to enhance breast feeding requires close contact between the mother and infant.[30] During the oral phase of swallowing, it has been shown sonographically that as the infant’s tongue is lowered, a decrease in negative pressure (increase in vacuum) is applied to the nipple and a bolus of milk fills the oral space between the nipple and the soft palate. As the tongue moves up toward the palate, the negative pressure increases (the vacuum decreases) and the bolus is moved from the oral cavity into the pharynx. In normal breast-feeding infants, the oral bolus constantly moves into the pharynx during each suck cycle. Movement of the tongue in breast-feeding produces little distortion of the nipple as opposed to bottle-feeding.[29,30] After one or more suck cycles, sufficient milk accumulates in the pharynx to trigger the pharyngeal swallow. From previous studies, it seems that ultrasonography could be a possible tool in the evaluation of the suckling of infant/children, although there has been no quantitative data that could help with the clinical diagnosis of dysphagia up to now.

CONCLUSION

The evaluation of the swallowing function in pediatric subjects requires a team approach and the incorporation of various instrumental evaluations, including VFSS, FEES, oximetry, and ultrasonography. Ultrasonography is an ideal tool for observing the soft tissues including the tongue and mouth floor muscles, and it has been implemented in assessing the suckling movements of infants. Although more research is required, it seems that ultrasonography, a portable, noninvasive and radiation-free device, could be a possible adjunct tool in the evaluation of the swallowing function in infants and children.

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小兒吞嚥障礙之評估 - 第二部分

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在第一部分中主要介紹小兒吞嚥的特點、小兒與成人口咽構造上的差異以及小兒常見疾病的吞嚥問題；這個部分主要探討小兒吞嚥功能的評估。對於小兒族群吞嚥功能的評估需要團隊的合作、跨領域的結合以及不同儀器的檢查，才能建立正確的診斷並安排適當的治療計畫，在臨床上是極富挑戰性的任務。本文介紹臨床上小兒吞嚥評估的重要病史及理學檢查；並且探討目前應用在小兒吞嚥評估上不同的儀器檢查：包含了錄影螢光吞嚥檢查(videofluoroscopic swallowing study)、光纖內視鏡吞嚥檢查(fiberoptic endoscopic evaluation of swallowing)、血氧偵測儀(oximetry)以及超音波(ultrasonography)這些檢查的臨床應用、優點以及使用上的限制。對於超音波在小兒吞嚥評估上的應用、檢查技術以及相關解剖構造在超音波影像的呈現亦有詳細的敘述。超音波由於方便攜帶、無侵入性以及不具放射線，非常適合用在小兒族群的檢查。雖然仍需更多研究證據佐證，目前初步的文獻指出超音波可以用於觀察吞嚥的過程、爲小兒族群吞嚥功能的評估提供額外的資訊。（台灣復健醫誌 2013；41(3)：163 - 171）

關鍵詞：吞嚥障礙 (deglutition disorders)，小兒 (pediatrics)，超音波 (ultrasonography)

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