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Cough, Choke, Sputter: The Evaluation of the Child with Dysfunctional Swallowing

David N. Tuchman, M.D.
Department of Pediatrics, Division of Pediatric Gastroenterology and Nutrition, The Johns Hopkins Hospital, Baltimore, Maryland, USA

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The clinical approach to the child with impaired or dysfunctional swallowing should include consideration of factors important in this age group, such as development of normal oromotor reflexes, the relationship between oral feeding and pulmonary function, the effect of nonnutritive sucking on growth, and the effects of impaired swallowing on the development of chronic lung disease. This paper will provide the reader with a pediatrician's perspective on the clinical evaluation of the swallowing-impaired child and review the strengths and weaknesses of currently available diagnostic tests.

Growth and Development of the Swallowing Apparatus

During gestation, deglutition first occurs at approximately 16–17 weeks [1]. Swallowing that occurs in utero plays an important role in maintaining normal amniotic fluid volume. It has been estimated that the normal fetus at term swallows approximately 450 ml of amniotic fluid per day (total amniotic fluid volume is 850 ml) [2]. Conditions that interfere with normal in utero swallowing (e.g., anencephaly with absent or decreased frequency of swallowing) may result in the development of polyhydramnios.

Address reprint requests to: David N. Tuchman, M.D., Division of Pediatric Gastroenterology and Nutrition, Department of Pediatrics, The Johns Hopkins Hospital, 600 North Wolfe Street, Baltimore, MD 21205, USA

Major changes in the size and relative location of components of the oral and pharyngeal cavities occur during the postnatal period [3]. These are discussed in detail elsewhere in this issue. It should be stressed that developmental changes are clinically relevant since interpretation of pediatric imaging studies should take into account age-related topographical differences.

Maturation of Feeding

In the normal infant, the oral phase of swallowing is characterized by a pattern known as suckle feeding [4, 5]. Suckle feeding, or suckling, refers to motion of the lower jaw and tongue compressing the upper jaw and palate. During suckling, the tongue, lip, and mandible move synchronously to create negative intraoral pressure that alternates with compression, an action that promotes fluid delivery from a nipple. Suckle feeding is followed by the development of transitional feeding, which occurs at 6–36 months. Subsequently, mature feeding takes place, characterized by biting and chewing. Maturation of feeding behavior occurs mainly as a result of central nervous system development, with motor activity being directed by higher centers such as the thalamus and cerebral cortex [5].

Swallowing Function in the Preterm Infant

An important clinical issue to consider when dealing with the preterm infant is the relationship between deglutition and breathing. Although premature infants are able to suckle feed at a gestational age of approximately 34 weeks, successful oral feeding requires coordination of swallowing and breathing. Poor integration of these activities may result in respiratory difficulties such as aspiration.

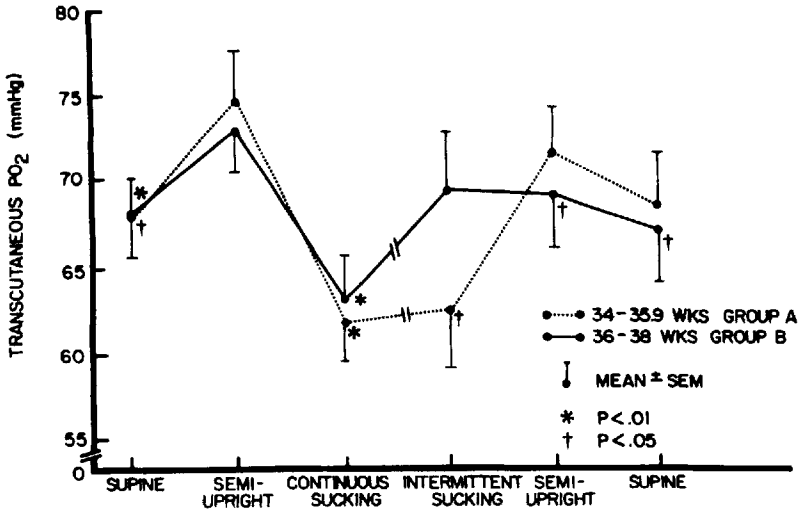

Fig. 1. $TcPo_2$ during continuous and intermittent sucking as compared with supine and semi-upright control periods. Group A, *dotted line*; group B, *solid line*. Data are mean ± SEM, and compared with initial upright control period. $*P<0.01$; $^{\dagger}P<0.05$). Note $TcPo_2$ was significantly lower during supine as compared with semi-upright control period prior to feeding, and remained lower in group B after completion of feeding. Reproduced with permission of Shivpuri et al. *J Pediatr 103:*285–289, 1983

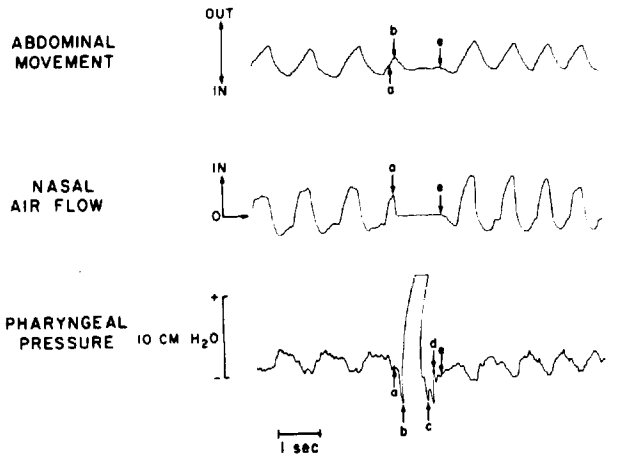

Fig. 2. Polygraphic tracing of a spontaneous swallow interrupting inspiration. At *a* the airway closes in midinspiration at swallow onset; *b* marks the cessation of inspiratory effort (outward movement of the abdomen) and onset of pharnygeal pressure peak; at *c*, the pharyngeal pressure falls to below peak inspiratory level and remains low until *d*; and at *e*, the airway opens and expiratory flow commences. Reproduced with permission of Wilson et al. *J Appl Physiol Respir Environ Exercise Physiol 50:*851–858, 1981

Shivpuri and his co-workers studied the effects of oral feeding on respiratory response in preterm infants grouped according to gestational age; group A included infants 34–35.6 weeks of age and group B, infants 36–38 weeks [6]. These investigators measured airflow using a nasal pneumotachometer and monitored blood gas levels with transcutaneous electrodes. During feeding by continuous sucking, minute ventilation decreased in both groups of infants, although it fell to a greater degree among subjects in group A. The fall in minute ventilation occurred secondary to a decrease i both tidal volume and respiratory frequency a resulted in a decrease in pO_2 (Fig. 1).

Wilson and co-workers evaluated the coordi tion of breathing and swallowing in preterm i fants [7]. A change in abdominal circumferenc recorded by a respiratory bellows strapped acro the abdomen, was used to identify different phas of respiration. Nasal airflow was measured wi a flowmeter and swallows were identified by cha ges in pharyngeal pressure measured using a sali filled catheter. These workers found that swallo occurred during inspiration or expiration and r sulted in an interruption of airflow that lasted a proximately 1 s. A polygraphic tracing demo strating the effect of a swallow on the respirato cycle is shown in Fig. 2. It was concluded th preterm infants are unable to breath and swallo simultaneously.

Importance of Nonnutritive Sucking

Nonnutritive sucking (NNS), defined as rhythm movements on a nonfeeding nipple, may impro weight gain during gavage feeding in preterm i fants. Bernbaum et al. studied the nutritional e fects of nonnutritive sucking in a group of lo birth-weight infants receiving formula by gava (bolus feeding by enteral tube) [8]. Infants in th study group received oral stimulation using a no feeding pacifier during all nasogastric feeding Control infants received nasogastric feeding wit out oral stimulation. Although both groups of i fants gained weight, study infants (the NNS grou gained significantly more weight per week than th control group. It was interesting that the differen

in weight gain occurred despite equivalent energy intake in the two groups. The mechanism(s) for greater weight gain in the NNS group is not known. One theory suggests that NNS results in more efficient nutrient absorption. This may occur secondary to an effect on gastrointestinal transit time or to stimulation of lingual lipase. Lingual lipase is an enzyme released during oral feeding from glands at the base of the tongue, which promotes intragastric lipolysis and enhanced absorption of fat [9]. An alternative hypothesis is that NNS may decrease energy requirements by decreasing the infant's activity or restlessness [10, 11].

Paludetto et al. examined the relationship between NNS and pulmonary function by evaluating the effect of NNS on transcutaneous oxygen tension in preterm infants [12]. They found that pO_2 increased during NNS in infants of gestational ages between 32 and 35 weeks. In a subsequent study, this same group of investigators determined that NNS was associated with an increase in respiratory frequency and that changes in pulmonary function that occur during oral feeding (i.e., nutritive sucking) appear to be unrelated to the action of sucking per se [13]. The mechanisms accounting for the differing effects of nutritive vs. nonnutritive on pulmonary function remain to be determined.

Pediatric Patients at Risk for the Development of Dysfunctional Swallowing

In clinical practice, pediatric patients at risk for the development of dysfunctional swallowing include infants and children with disorders of the central nervous system such as cerebral palsy, mental retardation, and brain injury secondary to infection or trauma. Other groups include premature infants with poor coordination of breathing and swallowing, infants with long-term deprivation of oral feeding, and children with behavioral feeding problems.

In the severely affected child, poor oral and/or pharyngeal function may lead to decreased energy intake and result in the development of protein-energy malnutrition. Because of its deleterious effects on the immune system and muscle strength, protein-energy malnutrition is associated with increased susceptibility to infection [14]. Dysfunctional swallowing may also lead to repeated episodes of aspiration, with subsequent development of chronic pulmonary disease. In the severely impaired child, repeated pulmonary infections become increasingly more debilitating in the face of worsening nutritional status.

Dysfunctional Swallowing and Gastroesophageal Reflux

In addition to the problem of dysfunctional swallowing, many neurologically impaired children suffer from an associated dysfunction involving the gastroesophageal junction, known as gastroesophageal reflux (GER). This may be defined as dysfunction of the distal esophagus leading to frequent return of stomach contents into the esophagus [15]. In children with central nervous system disease, the incidence of GER has been reported to be as high as 75% [16, 17]. The mechanism accounting for this phenomenon is unknown, although several factors may be involved, including habitual aerophagia, frequent recumbent positioning, diaphragmatic distortion secondary to kyphosis and scoliosis, and the effect of brain injury on function of the lower esophageal sphincter.

The child with impaired swallowing has a poorly protected airway and, consequently, an episode of acid reflux may result in severe pulmonary conditions such as bronchospasm, pneumonia, or apnea. The type of pulmonary response that occurs following an episode of acid reflux may depend on the region of the gastrointestinal tract and/or tracheobronchial tree stimulated by the refluxed material [18]. It has been demonstrated in animal and human studies that esophageal acidification may stimulate acid receptors in the esophageal mucosa and, via a reflex mediated by the vagus nerve, result in bronchospasm [19, 20]. Alternatively, direct tracheal aspiration of acid may result in reactive airway disease (bronchospasm) and/or aspiration pneumonia [18]; acid stimulation of the larynx may give rise to apnea, especially in infants [21].

Diagnostic Evaluation of the Pediatric Patient with Dysfunctional Swallowing

Feeding History

The diagnostic approach to the pediatric patient with dysfunctional swallowing should include a feeding history. However, obtaining an accurate feeding history may be complicated by a number of factors. First, pediatric patients with severe impairment of swallowing frequently include those with limited cognitive abilities. These patients are unable to report symptoms associated with oropharyngeal and/or esophageal dysfunction. Under these circumstances, the feeding history should be obtained from those persons directly involved in caring for the child; these may include a feeding specialist (i.e., occupational therapist) as well as

the primary caretaker and/or parent. Second, it has been our experience that severely handicapped children with dysfunctional swallowing often aspirate without coughing, a phenomenon known as "silent aspiration." A similar condition has been described in adults [22]. Consequently, it may be difficult to predict accurately which food substances are swallow-safe based on findings from a clinical examination or feeding history.

Despite these difficulties, a feeding history should be obtained. Questions should include the method of feeding (i.e. use of spoon and/or cup), head, neck, and body position during feeding; consistency of food tolerated (i.e., liquids, purees, solids); ability to chew; problems with drooling; history of gagging, choking, or coughing prior to, during, or following a swallow; and the amount of time required to feed. In infants, questions regarding the size and type of nipple are important. Symptoms that suggest the presence of GER include a history of regurgitation, vomiting, nighttime coughing, vomitus on the pillow in the morning, or ruminating. Esophagitis secondary to GER may present with hematemesis, refusal of food, and unexplained irritability.

A complete nutritional assessment is an essential part of the evaluation of the child with dysfunctional swallowing. Clinical goals should include the following: (1) determine the patient's current nutritional status (i.e., degree of acute and/or chronic malnutrition, specific nutrient deficiencies); (2) estimate energy and protein requirements for establishing optimal growth; and (3) outline a plan for providing the route and type of feeding: enteral feeding using a nasogastric or gastrostomy tube, use of oral supplements, or specialized formulas. Consultation with a registered dietitian trained in pediatric nutrition will greatly assist the practitioner in planning a comprehensive nutritional program for these patients.

Physical Examination

Physical examination of the child with dysfunctional swallowing should include examination of oral and pharyngeal reflexes, with particular emphasis on developmental reflexes. This topic has been reviewed in detail by Morris [23]. The oral cavity should be inspected for evidence of structural abnormalities. If structural abnormalities are found and/or are suspected in the pharynx, consultation with an otolaryngologist may be indicated. Presence or absence of a gag reflex should be noted, including the existence of a "hyperactive" gag reflex. Lack of a gag reflex is a contraindication to oral feeding, while a hyperactive gag results in significant feeding difficulties.

Feeding Trial

An essential portion of the physical examination is the observation of a feeding trial. The diagnostic yield of this part of the examination will be greatly increased if it is performed in collaboration with a speech-language pathologist or occupational therapist trained in the evaluation of swallowing disorders. Caretakers should be encouraged to bring feeding instruments and foods from home for use during the feeding trial. "Provocative" foods should be fed to the patient so that swallowing-related symptoms reported by the primary caretaker may be observed by trained personnel. During feeding the following should be noted: position of the head, neck, and body during swallowing; abnormal feeding behaviours such as tongue thrust or aversion of the mouth; and symptoms of choking, gagging, or ruminating.

Diagnostic Tests of Swallowing Function

Following the initial evaluation of the swallowing impaired child as outlined above, additional information is often required to manage these complicated patients. Specialized tests of deglutition will allow one to derive broad definitions of swallowing abnormalities. Unfortunately, these examinations are mainly descriptive and provide the clinician with limited data on specific pathophysiological mechanisms.

Videofluoroscopy. At the present time, videofluoroscopy is the procedure of choice for evaluating the pediatric patient with impaired swallowing. It is a widely available test and provides the best means for determining oral, pharyngeal, and esophageal anatomy. This technique documents the presence of aspiration and provides objective evidence of oral and pharyngeal incoordination. In addition, we use videofluoroscopy to identify children in whom oral feeding may be contraindicated (especially patients with "silent aspiration") and to determine which bolus characteristics of food are swallow-safe (i.e., size, consistency). Videofluoroscopy does not, however, provide quantitative data on the function of oral and pharyngeal structures involved in deglutition.

Pharyngeal Manometry. Manometry remains the best method for evaluating pharyngeal and esophageal motor function, including pharyngeal peristalsis, response of the upper esophageal sphincter (UES) to swallowing, and esophageal peristalsis

Intraluminal pressures in the oropharynx can be measured using either water-perfused catheters connected to a low-compliance perfusion pump or intraluminal strain gauges [24].

In children, manometry has been mainly used to investigate esophageal function in those with gastroesophageal reflux and other esophageal motor disorders [25]. More recently, this technique has been used to evaluate upper pharyngeal motor disorders. Staiano et al. demonstrated incomplete relaxation and incoordination of the upper esophageal sphincter in response to swallowing in children with disorders of deglutition complicated by pulmonary aspiration [26]. Sondheimer examined upper esophageal sphincter and pharyngeal motor function in infants with gastroesophageal reflux [27]. She found no difference in resting UES pressures and pharyngeal motor function in patients compared to normal controls.

As discussed by Dodds et al., recording the response of the pharyngoesophageal region during deglutition is complicated by a number of factors [28]. Motor events in the hypopharynx occur at a rapid rate and therefore recording equipment must have the ability to respond rapidly. This requires the use of expensive equipment operated by trained personnel. Second, the pressure profile of the upper esophageal sphincter is asymmetrical, with higher pressures noted in the anterior-posterior direction. Close attention must be given to the spatial orientation of the recording device while recording in the UES. Third, during deglutition there is significant axial movement of the recording catheter and oropharyngeal structures. This may result in a significant recording artifact. Recently, investigators have used a sleeve recording device – the Dent sleeve – to minimize the effects of catheter and sphincter movement [29]. Finally, manometry does not provide information on intraluminal events, such as the movement of fluid in response to recorded pressure changes. Simultaneous recording of videofluoroscopic images and manometric tracings has allowed investigators to correlate motor events with the intraluminal movement of substances [30]. The use of this technique has not been reported in children. At the present time, manometry is not a routine part of our clinical evaluation of the swallowing-impaired child, but is reserved for instances in which a specific esophageal motor disorder is suspected.

Diagnostic Tests for Gastroesophageal Reflux

A large subgroup of infants and children with neurologic impairment and dysfunctional swallowing also experience gastroesophageal reflux (GER). A clinical diagnosis of reflux may be made in the patient with regurgitation, vomiting, and rumination, once other causes of vomiting have been excluded (i.e., anatomical, infectious, central nervous system, metabolic). In the absence of regurgitation and vomiting, GER should be suspected in the patient with chronic, unexplained night-time coughing, refusal of food, irritability, and a history of gastrointestinal blood loss (either gross or microscopic). Gastrointestinal bleeding suggests the presence of reflux esophagitis.

The presence and severity of GER may be determined by overnight pH monitoring of the distal esophagus. This test is indicated if (1) documentation of significant GER is required, for example, prior to a surgical antireflux procedure or (2) there is a clinical suspicion of reflux-related pulmonary disease and correlation between a reflux episode and a significant pulmonary event, such as apnea or bronchospasm, is sought. Disadvantages of this technique are that it is an invasive procedure, although minimally, and an overnight hospital stay is usually required. Reflux esophagitis may be diagnosed by upper endoscopy and biopsy.

Ultrasonography

Ultrasonography represents a new diagnostic modality for the evaluation of the swallowing-impaired individual [31]. This is a noninvasive test that allows visualization of the motion of structures in the oral cavity, such as the tongue and floor of the mouth, during feeding and deglutition. To obtain an image, a transducer is placed in the submental region and the beam is aimed toward the tongue. Weber et al. have used this technique to identify feeding movements of oral structures in healthy breast-fed and bottle-fed infants [32]. Major disadvantages of ultrasound include (1) poor visualization of the oropharynx secondary to an acoustic shadow cast by bony structures in the neck and (2) lack of standardized measurements. Currently, ultrasonography should be considered a research technique in the evaluation of the child with dysfunctional swallowing.

Summary

Successful evaluation of the pediatric patient with dysfunctional swallowing requires an awareness of developmental and nutritional age-related issues. Diagnostic work-up should include a complete history and physical examination, observational feeding trial, nutritional assessment, and videofluoros-

copic swallowing study. To assist with the diagnostic evaluation, the pediatrician should enlist the aid of a speech-language pathologist, occupational therapist, and pediatric dietitian with experience in this field. An interdisciplinary approach to the swallowing-impaired child is essential for providing optimal care for these often difficult to manage patients.

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