

Swallowing Function and Medical Diagnoses in Infants Suspected of Dysphagia

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ABSTRACT. *Objective.* There has been an increase in infant swallowing disorders as a result of improved survival for infants born prematurely or with life-threatening medical disorders. These infants often have multiple health issues and an increased risk of respiratory complications. However, there is little understanding of the biomechanics of infant swallowing disorders. Therefore, the objectives of this study were to determine 1) the percentage of dysphagic infants who experience laryngeal penetration, aspiration, or nasopharyngeal backflow; 2) reasons for laryngeal penetration/aspiration; 3) whether infants with laryngeal penetration/aspiration clear their airway; and 4) the relationship between swallowing disorders and medical diagnoses.

Methods. Patients included 43 infants who were referred for videofluoroscopic swallowing studies in a university-affiliated pediatric medical center. Medical charts were reviewed. The videofluoroscopic swallowing studies were recorded on videotape, and each swallow was analyzed for laryngeal penetration, aspiration, nasopharyngeal backflow, cough, airway clearance, and reason for penetration/aspiration. Statistics included χ^2 for non-parametric data and measures of central tendency for numeric/timing data.

Results. More than half of the infants experienced laryngeal penetration, aspiration, or nasopharyngeal backflow; however, the first occurrence of these events was after multiple swallows. Only 3 infants experienced laryngeal penetration and aspiration on the first swallow and all 3 had an absent pharyngeal response. Premature infants experienced significantly more nasopharyngeal backflow. Material in the pyriform sinuses before pharyngeal swallowing was associated with penetration/aspiration. In episodes of laryngeal penetration, all patients were able to clear their airway during the swallow without a cough. Almost all infants (8 of 9) who aspirated did not cough or clear their airway.

Conclusions. This study demonstrated that most infants suspected of dysphagia showed overt abnormalities: laryngeal penetration, aspiration, and/or nasopharyngeal backflow on the videofluoroscopic swallowing study. Most of these infants did not demonstrate abnormalities in the first few swallows but displayed deterior-

ation in swallowing function as they continued to feed. Thus, radiographic assessments in infants must examine multiple swallows. The high incidence of silent aspiration demonstrates the necessity of a videofluoroscopic assessment to evaluate swallowing function in these infants. *Pediatrics* 2001;108(6). URL: <http://www.pediatrics.org/cgi/content/full/108/6/e106>; aspiration, dysphagia, laryngeal penetration, prematurity, pneumonia.

ABBREVIATIONS. MBS, modified barium swallow; SD, standard deviation.

There has been an increase in infant swallowing disorders as a result of improved survival rates for infants born prematurely or with life-threatening medical disorders. These infants often have multiple health issues and an increased risk of respiratory complications. Disorders of sucking and swallowing in infants are the result of multiple medical problems, may further exacerbate health, and cause respiratory complications. Despite the recent proliferation of research in adult swallowing disorders, there has been very little research on infant swallowing function and pathophysiology. Furthermore, the parameters that define adult swallowing and dysphagia cannot always be applied to the infant because of differences in the relationship of anatomic structures and lack of neurologic maturation.

Differences in the relationship of anatomic structures and neurologic immaturity account for variations in biomechanics of the infant swallow. The hyoid, larynx, and epiglottis (superior cartilage of the larynx) lie at a higher level than in the adult.¹⁻³ The infant often collects material in the valleculae during multiple sucks with the pharyngeal stage triggering from the valleculae.⁴ In 2 studies of infants with normal oropharyngeal swallowing function, none of the infants exhibited any spillover of material into the pyriform sinuses before initiation of the pharyngeal response.^{4,5} Infants with normal swallowing function never exhibit penetration of material into the supraglottic area and do not have aspiration of material below the vocal folds.^{2,4,5}

A strong relationship has been established between laryngeal penetration/aspiration and pneumonia.⁶ Nasopharyngeal reflux has been associated with apnea, choking, and a history of pneumonia in the infant.⁷⁻⁹ Preterm infants who were nursed in the head-elevated tilt position, altering swallowing function, were found to have significantly fewer brady-

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cardic or hypoxemic episodes when compared with a horizontal position.¹⁰ Despite the strength of the relationship between dysphagia and respiratory complications, there is little understanding of the biomechanics of infant dysphagia. The objectives of this study were to determine 1) the percentage of infants who are suspected to have dysphagia and who experience nasopharyngeal backflow, laryngeal penetration, or aspiration; 2) the biomechanical cause of laryngeal penetration/aspiration; 3) the percentage of infants who experience penetration/aspiration and who clear their airway; and 4) the relationship between the results of the modified barium swallow (MBS) and medical diagnoses.

METHODS

Patients

The Institutional Review Board of the University of Tennessee-Memphis and Le Bonheur Children's Medical Center approved this retrospective study. Patients included 43 consecutive infants who were younger than 1 year and referred for videofluoroscopic swallow studies within a 1-year period. There were 26 girls and 17 boys with a mean age of 5.25 months (standard deviation [SD]: 3.38 months) and a range from 1 week to 11.5 months. The reasons for referral included the following: rule out aspiration (18); gagging, coughing, or vomiting (8); failure to thrive (7); respiratory distress (4); difficulty feeding (3); wean from gastrostomy tube (1); apnea (1); asthma (1); cleft palate (1); and bradycardia (1). Each infant had more than 1 medical diagnosis as reported in the medical records and history (Table 1).

Procedures

Infants were seen for a videofluoroscopic examination (MBS) of oral, pharyngeal, and cervical esophageal transits. A General Electric (Milwaukee, WI) SFX2 table unit fluoroscope was used, and the study was recorded on a Panasonic (Division of Matsushita Electric Corporation of America, Secaucus, NJ) AG-MD830 video-

cassette recorder (S-VHS). A For Video Timer (Japan) was interfaced with the videocassette recorder, which superimposed timing information (hours, minutes, seconds, and hundredths of seconds) on the videotape image.

The infants were seated approximately 45° upright in a Tumbleforms Feeder seat (Jackson, MI) and viewed in the lateral projection. A 40% wt/wt (60% wt/vol) E-Z EM premixed liquid barium suspension was administered using a bottle and Ross Similac Infant Nipple & Ring (Columbus, OH). The hole in the nipple was enlarged to 3 mm with a scalpel, connecting the hole and crosscut, allowing the slightly thicker barium suspension to flow through the nipple.

Infants were fed by the parent or the clinician. The feeding protocol¹¹ began by presenting the infants with the bottle and nipple. If there was no aspiration on the initial swallows, then the infant was allowed to suck on the bottle until there was a change in swallowing function, 2 ounces were finished, or the infant refused to suck. For minimizing radiation exposure, the fluoroscopy unit was turned on every 15 to 30 seconds to visualize 1 or 2 swallows. The fluoroscopy unit was run continuously only when swallowing function changed, usually signaled by spillover of material into the pyriform sinuses before initiation of the pharyngeal response. Overall, maximum radiation exposure was kept to a limit of 1 to 2 minutes. When infants were unable to suck, a tuberculin syringe (without the needle) was used to administer liquid barium in 0.5- to 1.0-mL volumes.

The videotape was analyzed using a Panasonic AG-MD-830 videocassette recorder and JVC 13-inch monitor, which allowed for slow motion and frame-by-frame analysis. Slow motion and frame-by-frame analysis allows for evaluation of variables that are not easily visualized in real time. Every liquid swallow was analyzed for the following variables:

- Time of occurrence of laryngeal penetration as defined by material entering the vestibule or entrance of the airway to any extent down to the level of the true vocal folds¹²
- Time of occurrence of aspiration as defined by entry of material below the true vocal folds¹²
- Time of occurrence of nasopharyngeal backflow as defined by material posterior or superior to the soft palate
- Cough in the presence of laryngeal penetration and aspiration
- Ability to clear airway (penetration/aspiration)

TABLE 1. Medical Diagnoses of Infants Referred for Videofluoroscopic Swallow Studies

General Diagnostic Categories	Specific Diagnoses
Genetic/congenital malformations	Down syndrome (2) Fetal alcohol syndrome (1) Cornelia de Lange (1) Cleft palate (1) Tracheo-esophageal fistula and esophageal atresia (1)
Central nervous system insult	Anoxic brain injury (8) Hydrocephalus (4) Intraventricular hemorrhage (4)
Congenital infections	Cytomegalovirus (2) Rubella (1) Syphilis (1)
Respiratory	Pneumonia (21) Apnea (10) Respiratory distress (8) Asthma (4) Bronchopulmonary dysplasia (4)
Nutrition/gastroenterology	Gastrostomy tube (9) Gastroesophageal reflux (10) Failure to thrive (7) Difficulty feeding (3) Anemia (1)
Cardiovascular history	Congenital malformation (arteriovenous canal, ventricular septal defect) (2) Dysrhythmia (bradycardia, tachycardia) (2) Congestive heart failure (1) Thrombosis of the aorta (1)
Ear, nose, and throat	Laryngomalacia (5) Interarytenoid cleft (1) Bilateral vocal fold paralysis (1) Tracheomalacia (1)
Other	Prematurity (16)

- Biomechanical reason for laryngeal penetration or aspiration
- Time of initiation of each swallow beginning with upward movement of the jaw during sucking or onset of tongue movement with syringe-presented material

From these variables, it was possible to determine the length of time that the child was feeding until the first episode of laryngeal penetration, aspiration, or nasopharyngeal backflow from the onset of the study.

Four to 5 swallows per videotape were analyzed by another clinician at a separate time and compared to determine interrater reliability of laryngeal penetration, aspiration, and nasopharyngeal backflow; cough and ability to clear the airway; and the biomechanical reason for laryngeal penetration or aspiration. Interrater reliability was excellent with 100% agreement for laryngeal penetration and 98% agreement for the other variables. Statistical analyses involved a χ^2 for nonparametric data and measures of central tendency for numeric or timing data.

RESULTS

Of the 43 patients evaluated, laryngeal penetration was observed in 17 of 43 (40%), aspiration in 9 of 43 (21%), and nasopharyngeal backflow in 13 of 43 (30%). One infant had a cleft palate and consistent nasopharyngeal backflow without laryngeal penetration or aspiration. When this child was excluded from the population, nasopharyngeal backflow occurred in 12 of 42 (29%). As aspirated material must first enter the laryngeal introitus, all swallows with aspiration were considered to have laryngeal penetration. In total, 22 of the 43 patients (51%) experienced laryngeal penetration, aspiration, or nasopharyngeal backflow during the study. Of the 9 infants who aspirated, 6 of these infants had separate swallows for which there was laryngeal penetration without aspiration.

The following medical diagnoses were examined for occurrence of penetration, aspiration, or nasopharyngeal backflow: neurologic disorders (24 of 43 [56%]), prematurity (16 of 43 [37%]), pneumonia (21 of 43 [49%]), apnea (10 of 43 [23%]), and tube-fed (9 of 43 [21%]). In this population, infants who were born prematurely were significantly more likely to experience nasopharyngeal backflow ($\chi^2 = 4.06$; $P < .04$). There were no other significant relationships between medical conditions and laryngeal penetration, aspiration, or nasopharyngeal backflow. For example, 8 (38%) infants with a history of pneumonia showed laryngeal penetration, and 5 (24%) aspirated. In comparison, infants without history of pneumonia showed comparable rates of penetration (9 [43%]) and aspiration (4 [19%]). There were no age or gender effects for laryngeal penetration, aspiration, or nasopharyngeal backflow in this population.

The first occurrence of laryngeal penetration, aspiration, or nasopharyngeal backflow occurred later in the study and well beyond the first swallow for most patients. The first episode of laryngeal penetration occurred at a mean of 50.77 seconds into the study ($n = 17$; SD: 106.4 seconds; range: 0–423.49 seconds). For infants who aspirated, aspiration occurred later than laryngeal penetration with a mean of 65.41 seconds into the study ($n = 9$; SD: 135.96 seconds; range: 0–423.49 seconds). Nasopharyngeal backflow occurred earlier in the study with a mean time of 11.34 seconds into the study ($n = 13$; SD: 12.61 seconds; range: 0–32.28 seconds). The reasons for laryngeal

penetration with or without aspiration for 17 of the 43 infants included spillover of material into the pyriform sinuses while still sucking (12 of 17 [71%]), slow laryngeal closure or delayed pharyngeal response (2 of 17 [12%]), absent pharyngeal response (3 of 17 [18%]), and a combination of spillover and pharyngeal residue (1 of 17 [1%]). Examination of the reasons for penetration with or without aspiration with respect to timing of first occurrence revealed that the 3 infants who had an absent pharyngeal response experienced immediate laryngeal penetration and aspiration on the first swallow. The remainder of these infants ($n = 14$) experienced laryngeal penetration or aspiration later in the study.

When infants experienced laryngeal penetration without aspiration ($n = 14$), none of the infants coughed and all cleared their airway during the swallow. Airway clearance happened during laryngeal elevation as the arytenoid approached the base of the epiglottis, squeezing material back into the pyriform sinuses. All of the 14 infants had laryngeal penetration secondary to material in the pyriform sinuses before initiation of the swallow. Eight of the 9 infants who aspirated did not cough or clear their airway (silent aspiration). Only 1 infant coughed and was able to clear the airway.

Infants who were unable to suck had barium administered by syringe ($n = 8$). These infants were significantly more likely to aspirate (4 of 8; $\chi^2 = 5.02$; $P < .025$).

DISCUSSION

More than half of the infants (22 of 43) who were referred for dysphagia experienced laryngeal penetration, aspiration, or nasopharyngeal backflow. The overwhelming majority of patients did not demonstrate laryngeal penetration, aspiration, or nasopharyngeal backflow on the first or even the first few swallows. Thus, swallowing function deteriorated as the infant continued to swallow. The decline in swallowing function may be explained by the effects of fatigue or sensory adaptation. It is interesting that only 1 patient had any laryngeal surgery, and none of the patients had prolonged intubation, which might adversely affect laryngeal or pharyngeal sensitivity.

As expected, infants with an absent pharyngeal response experienced laryngeal penetration and aspiration on the first swallow. The remaining infants who penetrated or aspirated secondary to material in the pyriform sinuses before the swallow had their first episode of penetration or aspiration much later in the study, with a mean time after 1 minute. If the average suck and swallow cycle during videofluoroscopy lasts 1.48 seconds,⁴ then a child from this study may suck and swallow multiple times before first experiencing laryngeal penetration or aspiration. These results have implications for swallowing assessments. A swallowing evaluation, which examines only a few swallows, may miss laryngeal penetration, aspiration, or a change in the biomechanics of the swallow and may be inadequate for diagnostic purposes.

Coughing and airway clearance in the infant dif-

fers from the adult. In this study, all children who had laryngeal penetration without aspiration cleared their airway during the swallow without a cough, unlike adults with dysphagia, who cannot always clear the airway during the swallow and must cough to clear the material. Eight of the 9 infants in this study did not cough or clear their airway in response to aspiration (silent aspiration). Interesting is that these infants were not more likely to have pneumonia, which may reflect the small number of infants with silent aspiration in this study. Clinical observation of swallowing is not adequately sensitive to aspiration. The prevalence of silent aspiration in this study demonstrates the necessity of an assessment that views the oral and pharyngeal stages of swallowing, eg, radiographic or fiber-optic study. Furthermore, clinical observation of swallowing will not determine the cause of laryngeal penetration/aspiration, changes in swallowing function, or response to therapeutic intervention.

Only 1 infant experienced laryngeal penetration and aspiration from pharyngeal residue, a problem more commonly seen in adults. The most common cause of laryngeal penetration and aspiration was material in the pyriform sinuses before initiation of the swallow (either from spillover while still sucking or delayed pharyngeal response). The MBS captures only 1 time period, and the patient who does not aspirate during the MBS may aspirate during regular feedings. In the absence of laryngeal penetration/aspiration, abnormal swallowing function characterized by material in the pyriform sinuses before initiation of the swallow may be an indication of potential aspiration.

Almost half of the patients had a history of at least 1 episode of pneumonia. However, there was no correlation between pneumonia and aspiration or laryngeal penetration on the MBS. As mentioned above, the patient may not aspirate on the radiographic study yet still display abnormal swallowing function, which may be a predictor of aspiration and possible respiratory complications.

The results of this study revealed that infants who were born prematurely were significantly more likely to experience nasopharyngeal backflow. The nasal mucosa is chemosensitive as well as sensitive to touch, pain, temperature, and flow.¹³ In addition, human newborns and especially premature infants have apneic reflexes that arrest breathing, heart rate, and blood pressure.^{14–16} Nasopharyngeal backflow will stimulate the nasopharynx and may account for apneic responses seen during feeding in the infant.

The infants in this study were fed in an upright position in a Tumbleform seat. Because of gravity, the upright position would reduce the incidence of nasopharyngeal backflow. Results of a study by Jennie et al¹⁰ revealed that feeding preterm infants in a head-elevated tilt position significantly reduced bradycardic and hypoxemic episodes compared with a horizontal position. Although swallowing function was not examined in this study, nasopharyngeal backflow may have been reduced by the head position. Additional research is needed to determine the

effect of nasopharyngeal backflow on apnea, bradycardia, and hypoxemia.

CONCLUSION

The results of this study revealed that most infants who were suspected of having dysphagia showed overt abnormalities: laryngeal penetration, aspiration, and/or nasopharyngeal backflow on MBS. Most of these infants did not demonstrate abnormalities in the first few swallows but displayed deterioration in swallowing function as they continued to feed. Infants who demonstrated laryngeal penetration without aspiration could clear their airway without a cough. In contrast, infants who aspirated usually did not cough and clear their airway.

This study was retrospective, and the infants represented a heterogeneous group of medical diagnoses. The multiple medical diagnoses illuminate the vast array of causes of dysphagia in infants. However, it does not allow for thorough examination of the occurrence of dysphagia or type of swallowing disorders within specific populations. There is a need for additional research to examine swallowing function in infants with specific medical diagnoses. Such research would provide information on the epidemiology of swallowing disorders, progression of the swallowing dysfunction with maturation and therapeutic intervention, and the relationship between medical diagnoses and swallowing function.

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