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Improved Infant Swallowing After Gastroesophageal Reflux Disease Treatment: A Function of Improved Laryngeal Sensation?

Dana L. Suskind, MD; Dana M. Thompson, MD; Martha Gulati, MD; Penny Huddleston, MA, CCC-SLP; Donald C. Liu, MD, PhD; Fuad M. Baroody, MD

Objective: **The objective of this study was to describe improvements in pediatric swallowing after gastroesophageal reflux treatment.** ***Study Design:*** **The authors conducted a retrospective database and chart review at two tertiary care children's hospitals.** ***Participants:*** **Patients (21 males, 7 females) ranged in age from 1 to 32 months. All patients had clinical evidence of gastroesophageal reflux disease (GERD) as well as evidence of dysphagia with aspiration (laryngeal vestibule and/or trachea) or hypopharyngeal pooling on flexible endoscopic evaluation of swallowing and sensation testing (FEESST) or videofluoroscopic swallow study (VSS).** ***Intervention:*** **Each child underwent either medical or surgical intervention for control of their GERD.** ***Outcome Measures:*** **Outcome measures were change in laryngopharyngeal sensation and swallowing function with repeat swallow evaluation after GERD treatment.** ***Results:*** **A significant improvement in both swallow function and sensory testing was demonstrated after GERD treatment.** ***Conclusions:*** **GERD may result in decreased laryngopharyngeal sensitivity, which may contribute to pediatric swallowing dysfunction. Control of GERD may improve swallow function. These findings have important clinical implications that need further study.** ***Key Words:*** **Pediatric, gastroesophageal reflux, swallowing, laryngeal sensation, aspiration, dysphagia.**

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INTRODUCTION

Infant swallowing is a highly coordinated process. This process is dependent on intact sensorimotor reflexes that are integrated at the brainstem level. This coordination allows the suck–swallow–breathe sequence to occur without compromising respiration and protects the infant against aspiration. Alteration in this sequence can lead to feeding and swallowing difficulty, which may ultimately lead to aspiration. The occurrence of microaspiration in an infant or child may lead to respiratory complications such as aspiration pneumonia, asthma exacerbation, or apnea.[1] Aspiration may present clinically with coughing or choking, cyanotic spells while drinking, or may be silent without any clinical indicators.

Aspiration most commonly occurs in neurologically impaired infants and is less commonly seen in neurologically intact children.[2] Although a neurosensory etiology may easily explain this occurrence in a neurologically impaired infant, an underlying basis is more difficult to discern in the otherwise neurologically intact infant (e.g., no gross impairment such as cerebral palsy). Heuschkel refers to this as "isolated neonatal swallowing dysfunction" (INSD), which is a self-limited entity often presenting with "choking, cyanotic spells with feeding, and recurrent aspiration. . ."[3] He states that INSD can be an isolated disability without an obvious underlying etiology. Interestingly, however, all of the children in his article were placed on antireflux treatment secondary to the theorized risk of aspirating refluxate. The relationship among gastroesophageal reflux disease (GERD), microaspiration, and respiratory diseases is an accepted and frequently described scenario in the literature. Despite this, the actual pathophysiological basis by which a neurologically intact larynx, which should protect the lower airway, can allow microaspiration to occur is rarely discussed. Acid reflux in the esophagus is known as gastroesophageal reflux (GER). Once the refluxate leaves the esophagus and enters the pharynx, it is known as laryngopharyngeal reflux (LPR).[4] Of note, young children in contrast to adults have more frequent exposure of the pharynx to refluxate, suggested by their frequent regurgitation, and likely results from the

From the Section of Otolaryngology–Head and Neck Surgery (D.L.S., P.H., F.M.B.) and the Section of Pediatric Surgery (D.C.L.), University of Chicago, Chicago, Illinois, U.S.A.; the Division of Pediatric Otolaryngology (D.M.T.), Mayo Clinic and Mayo Eugenio Litta Children's Hospital, Rochester, Minnesota; and the Department of Preventive Medicine and Cardiology (M.G.), Northwestern University, Chicago, Illinois, U.S.A.

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Send Correspondence to Dana Suskind, MD, 5841 South Maryland Ave., MC1035, Chicago, IL 60637, U.S.A. E-mail: dsuskind@surgery.bsd.uchicago.edu

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high ratio of meal volume to gastric and esophageal volume.[1] A mechanism that may account for microaspiration would be LPR-related alteration in the laryngopharyngeal sensation, which could potentially alter laryngeal protective reflexes leading to microaspiration. We propose that LPR leads to functional anesthesia of the larynx, thereby altering the neurosensory function and airway protection and leading to microaspiration, particularly during the infant swallow process.

LPR is a very common process in infants and has been shown to potentially decrease laryngopharyngeal sensation in a subset of adults and children.[5–7] This partially insensate laryngopharynx has been shown to be associated with dysphagia, a reversible insult when the gastroesophageal reflux is appropriately treated with proton pump inhibitors.[5] Despite the established link between LPR and decreased laryngopharyngeal sensation, the ubiquitous nature of reflux in infants has led to a general lack of appreciation of decreased laryngopharyngeal sensation as a potential cause of microaspiration. We hypothesized that LPR has a negative impact on laryngopharyngeal sensation with resulting microaspiration/penetration in infants and children and that reflux treatment will have a positive impact on swallowing function in these patients. To test our hypothesis, we retrospectively reviewed the records of a series of neurologically intact infants and children (e.g., no evidence of cerebral palsy, seizures) from two different tertiary care children's hospitals with evidence of gross as well as microaspiration, swallowing dysfunction, and LPR. These patients had their swallow function and laryngeal sensitivity evaluated before and after treatment of GER.

METHODS

Study Design and Case Selection

A retrospective database and chart review of children from 0 to 3 years of age with suspected LPR and dysphagia demonstrated on videofluoroscopic swallow study (VSS) (institution 1) or flexible endoscopic evaluation of swallowing and sensation testing (FEESST) (institution 2) was undertaken between 2002 to 2004 and 2000 to 2002, respectively. Children included were those who had pre- and post-GER treatment swallow evaluations; children with significant neurologic disorders such as cerebral palsy or seizures were excluded. LPR was suspected on the basis of clinical symptoms with or without diagnostic testing. All children had evidence of aspiration (either deep vestibular penetration or tracheal aspiration) on VSS or FEESST or evidence of pooled secretions in the hypopharynx on FEESST, which has been found to correlate with decreased laryngopharyngeal sensation and increased risk of aspiration.[6] LPR was treated either with a course of antireflux medication (consisting of either an H-2 blocker and/or proton pump inhibitor) or antireflux surgery (Nissen fundoplication) as guided by the treating physician. A repeat VSS or FEESST was performed at the end of treatment. The retrospective review was approved by the University of Chicago and Mayo Clinic Institutional Review Boards.

Videofluoroscopic Swallow Study

A pediatric radiologist and a speech and language pathologist performed the examinations. Under fluoroscopy, a lateral view was obtained while the patient was seated upright. An anteroposterior view was only taken on children if there were concerns for anatomic asymmetry. Viscosities and textures of food tested were reflective of the child's current diet and were combined in a standardized fashion with barium. The patient's regular bottle and nipple were used during the examination. Radiation exposure was less than 1.5 minutes for infants and <2 minutes for children >12 months of age. Fluoroscopic examinations were recorded and frame-by-frame analysis in slow motion was completed after the examination by the speech–language pathologist. The following objective end points were evaluated: 1) evidence of laryngeal penetration or tracheal aspiration, 2) overall "swallow score" graded from 1 to 7, and 3) overall "pharyngeal impairment" graded from 0 to 3 as detailed in Table I.[8]

Flexible Endoscopic Evaluation of Swallowing and Sensation Testing

The FEESST examination was performed with the infant positioned in the upright or semireclined position in the lap of a caregiver providing gentle restraint. The flexible laryngoscope (FNL 10 AP Laryngoscope; Pentax Precision Instruments Corp., Orangeburg, NY) used is equipped with an accessory channel and interfaced to a calibrated air pressure device (AP-4000 Air Pulse Sensory Stimulator; Pentax) to allow for delivery of a duration (50 ms) and intensity (2.5–10 mm Hg)-controlled air pulse to the aryepiglottic fold to induce the laryngeal adductor reflex (LAR).[6,7,9–11] Four percent viscous lidocaine was applied to the outer surface of the scope before insertion in the nose. The tip of the laryngoscope was advanced to within 2 to 3 mm of the aryepiglottic fold. Starting at an intensity of 2.5 mm Hg, the intensity of the air pulse was increased in 0.5-mm-Hg increments to a maximum of 10.0 mm Hg. These air pulses were delivered to the aryepiglottic fold to induce the LAR. A swallowing assessment was performed with liquids and with a variety of textures if developmentally appropriate. The feeding parameters evaluated were laryngeal penetration and aspiration. During swallowing function assessment, if significant laryngeal penetration occurred, the feeding

TABLE I.

A. Swallowing Performance Status or Swallow Score (VSS).

1. Normal
2. WFL—abnormal oral or pharyngeal stage but able to eat regular diet without modification or swallowing precautions.
3. Mild impairment—mild dysfunction in oral or pharyngeal stage, requires modified diet or therapeutic swallowing precautions.
4. Mild-moderate impairment with need for therapeutic precautions. Mild dysfunction in oral or pharyngeal stage, requires modified diet or therapeutic swallowing precautions to minimize aspiration risk.
5. Moderate impairment—moderate dysfunction in oral or pharyngeal stage, aspiration noted on exam, requires modified diet and swallowing precautions to minimize risk of aspiration.
6. Moderate-severe dysfunction in oral or pharyngeal stage, aspiration noted on exam, requires modified diet and swallowing precautions to minimize risk of aspiration, needs supplemental enteral feeding support.
7. Severe impairment—severe dysfunction with significant aspiration or inadequate oropharyngeal transit to esophagus, NPO, requires primary feeding support.

B. Pharyngeal Impairment Score (VSS).

0. None
1. Mild
2. Moderate
3. Severe

VSS = videofluoroscopic swallow study.

assessment was stopped to prevent further aspiration events. The following objective end points were collected: 1) laryngopharyngeal sensation as determined by air pulse intensity in millimeters of mercury required to induce the LAR, which is viewed as a brief closure of the vocal cords, with accepted values for both adults and children as follows: <4 mm Hg = normal, 4 to 6 mmg Hg = moderate sensory deficit, and >6 mm Hg = severe sensory deficit; 2) the degree of hypopharyngeal pooling (recorded as none, minimal, moderate, or severe); and 3) evidence of laryngeal penetration or aspiration graded as follows: 0 = no aspiration, 1 = laryngeal penetration, and 2 = tracheal aspiration.

Statistical Analysis

Continuous data are expressed as the mean ± standard deviation. Comparison of specific variables was performed pre- and posttreatment. Comparisons between pre- and posttreatment were performed using Student *t* test for continuous variables and χ^2 test or Fisher exact test, when appropriate, for categorical variables. A two-tailed *P* value < .05 was considered statistically significant. Statistical analysis was performed using STATA 8.0 (College Station, TX).

RESULTS

Descriptive characteristics of this cohort are seen in Table II. Twenty-eight patients presented with clinical evidence of dysphagia. There were 7 females and 21 males with ages ranging from 4 to 42 weeks at the time of initial evaluation (not adjusted for prematurity) with a median age of 23.6 weeks. A history of prematurity was the predominant medical issue in 8 of 11 from institution 1 and 7 of 17 from institution 2 with 54% of the patients overall being born before 37 weeks gestation. Gestational age of premature infants ranged from 24 to 36 weeks with an average of 32 weeks. The patients were referred for swallow evaluation for a variety of clinical indicators ranging from coughing with feeds to history of aspiration pneumonia requiring tracheal intubation. All patients had clinical evidence of GERD, which was supported with adjunctive tests; five had an abnormal both barium swallow and pH probe, 13 had an abnormal barium swallow, and two had an abnormal pH probe. An abnormal barium swallow was defined as either multiple reflux episodes into the esophagus or demonstration of reflux episodes beyond the thoracic inlet. An abnormal pH probe was defined as a pH <4 for >12% of the 24-hour period. Twenty-two (79%) patients were placed on antireflux medication, and six (21%) underwent antireflux surgery (Nissen fundoplication). One of the children who underwent fundoplication underwent surgical treatment secondary to failure to thrive rather than failure of medical treatment.

All study participants demonstrated varying degrees of swallow dysfunction on VSS and FEESST (Table III). Swallow dysfunction ranged from deep penetration into the laryngeal vestibule with thin liquids to frank tracheal aspiration with all food consistencies. Pooling of hypopharyngeal secretions in patients undergoing FEESST was demonstrated in 15 of 17 as an indicator of decreased laryngopharyngeal sensation (Table III).[12] Those who underwent FEESST also had direct laryngopharyngeal sensory threshold testing. In all of these patients, the thresholds required to trigger the LAR were elevated with a mean of 6.3 ± 1.0 mm Hg air pulse pressure, indicating severe laryngopharyngeal sensory impairment. As illustrated in Figure 1, there is a strong positive relationship between depth of aspiration and the threshold required to elicit the LAR (ordinal logistic regression; χ^2 17.3, df = 1, $P < .0001$). In those who underwent VSS, the average "swallow score," evaluating both the oral and pharyngeal stages of swallowing, was 4.8 (moderate impairment) and the average pharyngeal impairment score was 1.8 (mild–moderate impairment) (Table III).

Dietary modifications were made in all patients (exact recommendations are known only for institution 1) from changing to a low-flow nipple (2 of 11) (high-flow nipples are generally used in premature infants) to thickening of feeds (5 of 11) to requiring an NPO status (no oral intake) with alternate routes of feeding secondary to inability to tolerate even thickened feeds (4 of 11). Of the four children who required alternate routes of feeding, two underwent laparoscopic gastrostomy tube in conjunction

TABLE II.
Descriptive Characteristics of the Study Population (N = 28).

Baseline Characteristic	N = 28
Gender: M/F (%)	21/7 (75/25)
Age at first swallow study (weeks)	23.6 ± 18.6
History of premature birth; number (%)	15/28 (54)
Adjunctive test; number (%)	
Barium swallow and pH probe	5 (18)
Barium swallow only	13 (46)
pH probe only	2 (7)
History only	8 (29)
Gastroesophageal reflux disease treatment; number (%)	
Medical	22 (79)
H2RA only	10 (45)
Proton pump inhibitor	12 (55)
Surgical	6 (21)
Time of treatment (weeks)	20.7 ± 15.4

Mean ± standard deviation.

TABLE III.
Baseline Characteristics of Swallow Function.

Method of Swallow Evaluation	N (%)
VSS	11/28 (39)
FEESST	17/28 (61)
Presence of aspiration (VSS and FEESST)	23/28 (82)
Aspiration location (%) (VSS and FEESST)	
Laryngeal vestibule (penetration)	8/23 (35)
Trachea (trachea)	15/23 (65)
Hypopharyngeal pooling (FEESST)	15/17 (88)
Sensitivity score (mm Hg) (FEESST)	6.3 ± 1.0
Swallow score (VSS)	4.8 ± 1.3
Pharyngeal impairment score (VSS)	1.8 ± 0.6

Mean ± standard deviation.
VSS = fluoroscopic swallow study; FEESST = flexible endoscopic evaluation of swallowing and sensation testing.

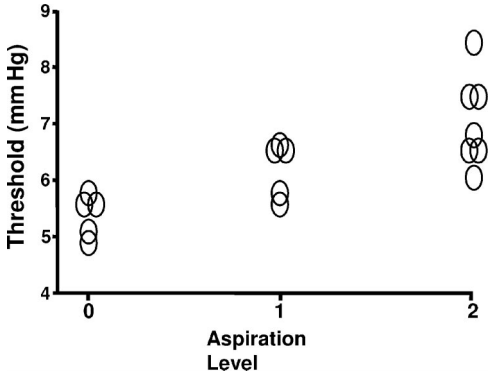

Fig. 1. Display of the laryngopharyngeal sensory thresholds (in millimeters of mercury) and depth of aspiration in the 17 patients assessed by flexible endoscopic evaluation of swallowing and sensation testing. Aspiration level: 0 = no aspiration, 1 = penetration, 2 = tracheal aspiration.

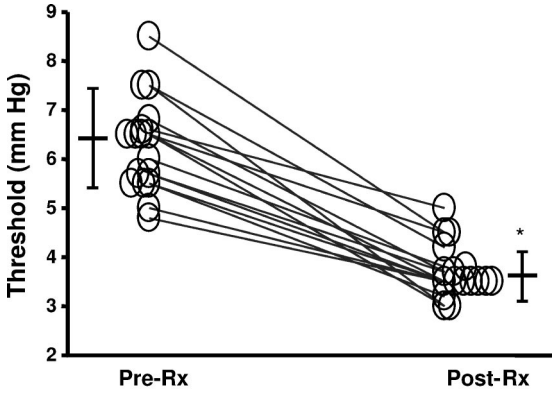

Fig. 2. Change in threshold required to elicit the laryngeal adductor reflex after treatment of gastroesophageal reflux disease using flexible endoscopic evaluation of swallowing and sensation testing. Individual values are plotted and the bars represent mean ± standard deviation. *$P < .0001$ versus pretreatment.

with Nissen fundoplication. Because of our positive clinical experience in the previous patients requiring an NPO status (i.e., they were able return to oral feeds after GER treatment), the subsequent two patients had temporary nasogastric tube placement until repeat VSS was performed after LPR treatment.

Repeat swallow evaluation was performed from 3 to 78.1 weeks postintervention with a median of 18 weeks. Whereas the pretreatment assessment yielded 23 of 28 (82%) patients with aspiration, the posttreatment assessment only showed 4 of 28 (14%) patients still aspirating, a significant reduction ($P < .001$) (Table IV). In the four children with continued aspiration, there were dramatic improvements from gross tracheal aspiration to minimal shallow penetration into the laryngeal vestibule, which translated clinically from being NPO into being able to tolerate oral feeds (with thickening). In addition, in those who had demonstrated hypopharyngeal pooling as their primary indicator of decreased laryngopharyngeal sensation, 14 of 15 ($P < .001$) had resolution of their pooling. Correlating with their improved swallowing, all patients who underwent FEESST testing demonstrated a significant reduction in the sensory threshold required to elicit the LAR reflex from 6.3 ± 1.0 to 3.7 ± 0.5 mm Hg ($P < .0001$) indicating improved sensation level (Table IV, Fig. 2). In addition, those who underwent VSS demonstrated significant improvement in both pharyngeal impairment scores and swallow scores with a reduction from 1.3 ± 0.6 to 0.1 ± 0.3 and 4.8 ± 1.3 to 2.9 to 1.6 ($P < .003$), respectively. These translate into qualitative equivalent of a change from mild–moderate pharyngeal impairment to basically normal pharyngeal function and from moderate swallowing impairment to mild swallowing impairment (Fig. 3).

Pharyngeal impairment score is a complex score involving evaluation of pharyngeal stasis (amount, location, and clearance), laryngeal elevation, laryngeal closure, pharyngeal transit time, laryngeal sensitivity, presence or absence aspiration, percentage aspiration, laryngeal or tracheal clearance after penetration or aspiration, base of tongue retraction, and timing of swallow. The swallowing

TABLE IV.
Posttreatment Outcome.

Characteristic	Pretreatment	Posttreatment	*P* Value
Presence of aspiration*	23 (82)	4 (14)	< .001
Aspiration location			
None	5 (18)	24 (86)	< .001
Penetration (vestibule)	8 (28)	4 (14)	NS
Aspiration (trachea)	15 (54)	0 (0)	< .001
Presence of pooling	15 (88)	1 (6)	< .001
Sensitivity score (mm Hg) (FEESST)†	6.3 ± 1.0	3.7 ± 0.5	< .001
Pharyngeal impairment score (VSS)‡	1.8 ± 0.6	0.1 ± 0.3	< .001
Swallow score (VSS)‡	4.8 ± 1.4	2.6 ± 1.6	.003

P value determined using the t-test for continuous variables and χ^2 test for categorical variables.
*N = 28.
†N = 17.
‡N = 11.
FEESST = flexible endoscopic evaluation of swallowing and sensation testing; VSS = videofluoroscopic swallow study; NS = not significant.

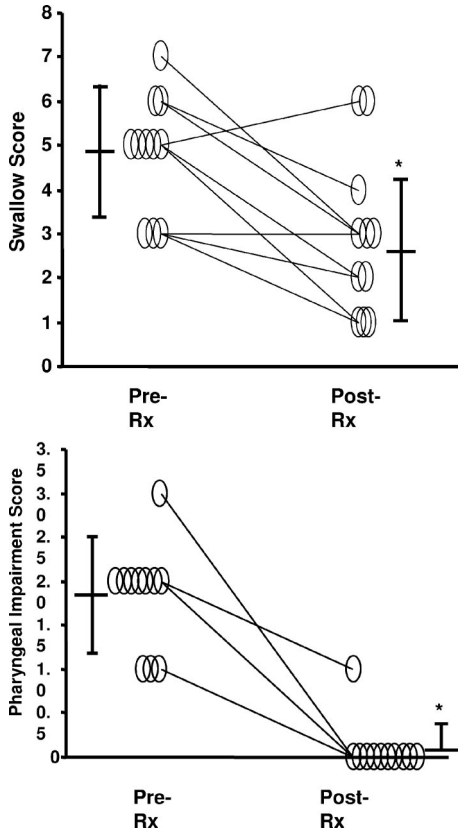

Fig. 3. (A and B) Change in videofluoroscopic swallow score and pharyngeal impairment score after treatment of gastroesophageal reflux disease. Individual values are plotted and the bars represent mean ± standard deviation. *$P < .003$ versus pretreatment.

score on the other hand evaluates both oral and pharyngeal phases of swallowing. The clinical implications of the improvement translated into 9 of 11 patients being able to resume age-appropriate, unrestricted diets; these 26 included two of the four who were unable to tolerate any type of oral intake before treatment. Two children who previously had gross aspiration requiring an NPO status and temporary nasogastric tube placements were able, after treatment, to eat orally by simply adding thickening agents to their feedings. Of note, one child whose aspiration had stopped on antireflux medication had recurrence of aspiration (documented on VSS) after his mother stopped the medication 1 year later on her own accord.

DISCUSSION

We have demonstrated for the first time that LPR may lead to impaired laryngopharyngeal sensation with resultant swallowing dysfunction and microaspiration in children. We have also clearly shown that aggressive reflux treatment may reverse these deleterious effects. The numerous detrimental effects of GERD/LPR on the pediatric upper and lower airways have garnered significant clinical attention as well as controversy in recent years.[14–16] Most of the previous observational studies described anatomic changes of the upper and lower airways associated with GERD such as subglottic stenosis and laryngomalacia.[16] The literature also discusses the association between GERD and lower airway pathologies such as aspiration pneumonia, cyanosis with feeding, and asthma, which implies microaspiration of refluxate as an etiologic factor. Most view this microaspiration as merely "isolated" rather than an indication of incompetence of the protective reflexes of the larynx.[3] Our data support our hypothesis that, in a subset of infants, there is subtle compromise of the sensory function of the laryngopharynx secondary to the effects of LPR/GERD. This leads to a depressed or absent laryngeal adductor reflex, which in turn leads to swallowing dysfunction and microaspiration.

In support of our hypothesis, previous authors have alluded to the potential relationship between laryngopharyngeal sensory dysfunction and GERD. Using FEESST, Aviv et al. demonstrated reduced laryngopharyngeal sensation in a subset of otherwise neurologically intact adults with dysphagia and GERD using FEESST.[6] They found that 3 months of GERD treatment using a proton pump inhibitor in those with dysphagia and GERD resulted in normalization of laryngopharyngeal sensation with improved swallow function and decreased posterior laryngeal edema. Link et al., while describing the feasibility of laryngeal sensory testing in children, also noted that children with underlying GERD had an overall decrease in laryngeal sensation in contrast to those without GERD. Interestingly, an additional clinical piece of evidence supporting our hypothesis is the fact that thickening of feeds is often the treatment of microaspiration in the presence of decreased laryngopharyngeal sensation. Thickening of feedings is also coincidentally a traditional method of GERD treatment in infants that has been shown to reduce the frequency of overt regurgitation and therefore probably the frequency of reflux that migrates into the pharynx and gains access to the larynx.[17,18] Thus, pediatricians may have already been unknowingly and indirectly treating GERD-related dysphagia through the traditional thickening of feeds.

It is theorized that gastric refluxate leads to edema of the posterior glottic region, causing decreased sensation and alterations in the laryngeal protective reflexes. The laryngeal adductor reflex results in glottic closure and cessation of respiration during swallowing and is triggered by exposure of the supraglottic mucosa to chemical or mechanical stimuli. This glottic closure prevents aspiration. When this reflex mechanism is disrupted by the deleterious effects of acid exposure, lack of appropriate laryngeal closure may in turn result in laryngeal penetration and aspiration. We suggest that this may be the link which connects GERD and lower airway disease.

Traditional methods for the evaluation of swallowing include bedside swallow evaluations and VSS. VSS allows indirect visualization of both the structural and functional components involved in swallowing.[19,20] One is able to indirectly evaluate laryngeal penetration and/or aspiration of barium as well as laryngeal sensitivity (in the form of cough when aspirated material stimulates the superior laryngeal nerve). An interesting aspect of the VSS studies in these patients is that the laryngeal penetration and aspiration did not generally occur on the first swallow for most patients. There appeared to be a functional deterioration as they continued to feed. If the speech pathologist

had not continued the evaluation beyond the initial swallows, the diagnosis of microaspiration in a number of these patients would have been missed. This is similar to the findings of Newman et al. in their evaluation of infants suspected of dysphagia.[21] These results indicate that swallow assessments in infants, which examine only a few swallows, may miss penetration and aspiration, and therefore may not be an adequate diagnostic modality. Recent interest has focused on flexible endoscopic evaluation of swallowing with sensory testing (FEESST). Although pediatric sensory testing has its potential limitations, it has been shown to correlate with altered laryngeal sensation in infants and children with neurologic disorders and GERD who are at risk for swallowing disorders. FEESST is felt to provide a more quantitative and direct picture of laryngeal sensitivity than VSS, although FEESST is not widely performed in young children. Although this method of testing may become the standard of workup with time and experience, VSS is currently the more common method of evaluation. In support of their clinical equivalence, Aviv found that when comparing FEEST with VSS with regard to directing dietary management, both provided similar clinical outcome in the dysphagic patient.[22]

We noted that there existed a subset of infants who presented with evidence of microaspiration and swallowing dysfunction whose dysphagia improved after treatment of their LPR. Two different diagnostic swallowing tests with identical end points, penetration and aspiration, were used at each institution. The severity of the swallowing dysfunction found ranged from laryngeal penetration requiring only thickening of feeds to gross aspiration requiring the patients to be NPO and having alternate routes of feeding. Four of the patients necessitated an "NPO status" as aspiration occurred with all consistencies of food; the first child who was one of our "initial observations" underwent laparoscopic Nissen fundoplication with a gastrostomy tube because of the concern regarding aspiration pneumonia. Because this child was able to resume oral intake 11 weeks postsurgery without restrictions, the following two children with severe aspiration (including one in whom the dysfunction was identified after intubation for severe aspiration pneumonia) had only temporary nasogastric tubes placed during the 6-week period when they were made NPO and received medical treatment for GERD. Both were able to resume oral feeds just 8 weeks after starting their and had no further evidence of dysphagia or aspiration. The other patient who required an alternate route of feeding was not placed on a medical treatment protocol for GERD and underwent surgical intervention. In all patients, repeat VSS or FEESST demonstrated significant improvement or resolution of their dysphagia and resumption of an oral diet. Only two children continued to require a minimal amount of thickening for persistent, yet mild, penetration. These children had both previously required alternate routes of feeding and had temporary nasogastric tubes placed.

Another interesting aspect of our patient population is the fact that many of the patients were 1 year of age or less at presentation. In addition, a vast majority had a history of prematurity without overt signs of neurologic impairment. None had gross neurologic sequelae such as cerebral palsy or seizure disorder. Obviously, the young age at presentation might lead to an underestimation of neurologic impairment, which might be uncovered in the future. Although the literature has demonstrated the larynx to have a significant ability to compensate for mild functional and anatomic abnormalities, it may be that this age group, especially with a developmental confounder such as prematurity, may still have less ability to compensate. Alternatively, the patient's skew toward this young age may be secondary to the fact that GER is significantly more common in younger children with the majority outgrowing it by 1 year.[23] In addition, when we evaluated differences in baseline characteristics between those whose aspiration completely resolved postreflux treatment versus those with residual penetration, the only significant finding was that those with residual penetration were significantly older at presentation than those with complete resolution.

Our study has certain limitations. It is a small, retrospective study from just two institutions. Certainly, a prospective study would be best to validate our findings. Furthermore, this study population was composed of those who were referred for a diagnostic examination, resulting in a selection bias. In addition, there was a lack of blinding as well as controls during the swallowing studies. Although we were able to document improved swallowing, this study could not exclude alternate causes for improved swallowing. Potential reasons for improved swallowing with time include overall neurologic development as well as removal of chronic aspiration/penetration with changes in feeding regimen. Because our population is young, it is plausible that a portion of the improvement found in swallowing function is maturational in origin. Certainly, the demonstration of improved laryngopharyngeal thresholds (in the FEESST group) correlating with improvement of clinical indicators (i.e., cessation of penetration/aspiration) is supportive of our hypothesis. In addition, Dezell has suggested that "isolated" laryngeal penetration may normally occur in nondysphagic infants (although interestingly, 91% of his patients have symptoms of either GER or vomiting) and was not a predictor for aspiration in contrast to adult populations.[24] Although we agree there may be occasional "isolated" laryngeal penetration without deleterious effect, our "penetrating" population (8 of 28) presented clinically with dysphagia and respiratory symptoms and their swallow alterations were deemed "significant" and with enough depth to merit feeding modification, which rectified their swallowing abnormalities. In addition the "normality" of Dezell's population could be questioned because the majority of his patients (91% [31 of 34]) were referred for GER or vomiting. We acknowledge that swallowing function improves with maturation, but we speculate that it could also be related to better control of GERD. In fact, one of our patients after being taken off his antireflux medication (Prevacid) had recurrence of both his reflux as well as his swallowing difficulties (documented on VSS). This further demonstrates the role of uncontrolled acid on swallowing dysfunction in an otherwise neurologically intact child. Other reasons for the

improved swallowing may be the fact that eliminating the chronic aspiration/penetration for a period of time in and of itself may have improved the swallowing mechanism.

In summary, this is a preliminary retrospective study evaluating the potential relationship of LPR and decreased laryngeal sensation. Our study suggests that LPR may lead to impaired laryngeal sensation with resultant dysphagia and microaspiration. It further suggests that treatment of acid reflux with antireflux medication or surgery can reverse the deleterious changes and thus improve swallowing in these children. Because of the frequent occurrence of reflux symptoms in infants and the often subtle signs of microaspiration, we believe that there is a subset of otherwise normal infants with microaspiration and swallowing dysfunction secondary to laryngeal effects of LPR. We propose that increased vigilance is necessary in approaching infants with LPR with directed questioning regarding coughing or choking with feeds or evidence of airway disease. Evaluation of swallowing function should be performed on those with signs of dysphagia or airway disease, because aggressive treatment of GERD may improve both their GERD and their dysphagia. Our preliminary observations certainly support this concept, because all children had clinical improvement in their microaspiration after medical or surgical treatment of GERD, correlating with significant improvements in their laryngopharyngeal sensation in those tested. These findings have important clinical implications and suggest that larger, prospective, randomized, controlled studies need to be performed to further define this relationship and to determine the optimal treatment for affected children.

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