Comparing videofluoroscopy and endoscopy to assess swallowing in bottle-fed young infants in the neonatal intensive care unit

Erika S. Armstrong, PhD, CCC-SLP[1], Jenny Reynolds, MS, CCC-SLP[2], Sandra Carroll, BS, OTR[2], Chrysty Sturdivant, BS, OTR[2], and Mustafa S. Suterwala, MD[3]

[1] Department of Communication Sciences and Oral Health, Texas Woman's University, Denton, TX, USA;

[2] Department of Physical Medicine, Baylor University Medical Center, Dallas, TX, USA;

[3] Division of Neonatology, Department of Pediatrics, Baylor University Medical Center, Dallas, TX, USA

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Corresponding author: Mustafa S. Suterwala, MD, Division of Neonatology, Baylor University Medical Center, 3500 Gaston Avenue, 3 Hoblitzelle, Dallas, TX 75246, USA. E-mail: Mustafa.Suterwala@BSWHealth.org. Phone: (214) 820-7604; fax: (214) 820-2370.

ABSTRACT

Objective: To determine the diagnostic accuracy of videofluoroscopy (VFSS) and endoscopy (FEES) in detecting laryngeal penetration and tracheal aspiration in bottle-fed young infants in the NICU.

Study Design: VFSS and FEES findings of 22 infants were compared to each other and to a composite reference standard in this prospective study. Sensitivity, specificity, positive and negative predictive values were calculated for each assessment.

Result: Agreement between VFSS and FEES was high (92%) for aspiration and moderate (56%) for penetration, with FEES detecting more instances of penetration. Compared to the composite reference standard, FEES had greater sensitivity and a higher negative predictive value for penetration than VFSS. Because of the low prevalence of aspiration, diagnostic accuracy could not be determined for aspiration for either assessment.

Conclusion: FEES appears to be more accurate in detecting penetration in this population, and both assessments are valuable tools in a comprehensive feeding and swallowing evaluation.

INTRODUCTION

The ability to safely and accurately assess swallowing function in high-risk newborns and young infants, especially in the neonatal intensive care unit (NICU), is of vital importance. Establishing these fragile infants on individualized feeding plans, with a pathway toward oral feedings, is critical for their health and neurodevelopmental well-being as well as timely discharge from the hospital. For many decades, the standard instrumental tool used to assess young infants has been the videofluoroscopic swallow study (VFSS).[1-7] However, in more recent years, fiberoptic endoscopic evaluation of swallowing (FEES) has become a viable option for assessing swallowing dysfunction in children, including newborns and young infants.[8-17]

While it is acknowledged that VFSS is not *the* definitive diagnostic assessment, it has been frequently assigned the label of "gold standard" because it was one of the earliest effective instrumental assessments.[18-19] This has resulted in FEES, as the relative newcomer, being compared to the "gold standard VFSS" in order to demonstrate its diagnostic accuracy in feeding and swallowing assessments. Prior studies have reported on the diagnostic accuracy of FEES compared to VFSS for detecting laryngeal penetration and tracheal aspiration in adult populations[20-24] and heterogeneous pediatric populations that included young infants as well as older children.[10,13] The adult studies reported high rates of agreement between VFSS and FEES (between 82 and 97%) and/or high sensitivities and specificities (between 70 and 100%) for both penetration and aspiration of thin liquids when comparing FEES against the VFSS standard. The agreement rates were high even though the two instrumental assessments are very

different from one another in the images they capture, and for the most part, the assessments were conducted hours or days apart rather than simultaneously.

The two pediatric studies had mixed results, with one study[10] reporting 100% agreement between VFSS and FEES and the other[13] reporting between 50 and 60% agreement. In one of the studies,[13] FEES appeared to have moderate sensitivity and specificity values (between 52 and 62%) for laryngeal penetration when compared to VFSS as the standard. For aspiration, however, FEES showed low sensitivity (22 to 28%) and high specificity (92%).

One recent study[25] conducted both a systematic review and a meta-analysis of previous studies comparing VFSS and FEES in adult patients. The researchers not only reported the selected studies' diagnostic accuracy of FEES compared to VFSS as the standard but also calculated sensitivity and specificity values for VFSS using FEES as the standard. They found that, in general, FEES had greater sensitivity for penetration and aspiration and VFSS had greater specificities. In addition, because there is no consensus as to which assessment should be used as the standard, these researchers compared both VFSS and FEES to a composite reference standard using the "OR" rule.[25] With this rule, a finding is considered positive if *either* assessment, VFSS or FEES, is positive; a negative finding requires both tests to be negative. Pooled analysis of the six selected studies revealed that FEES showed greater sensitivity than VFSS compared to the composite reference standard for both penetration and aspiration. Specificities were equivalent. Overall, values were high, ranging from 64% to 98%.

The results from all these studies suggest that both VFSS and FEES have high

diagnostic accuracy in detecting laryngeal penetration and tracheal aspiration in adults and children. The question of diagnostic accuracy for both VFSS and FEES in assessing newborns and young infants, however, still remains. Young infants differ from older children and adults not only in the relationships of their anatomical structures but also in the physiology of their swallows.[5,7,26] The sequential suck/swallow pattern that a neurologically immature infant demonstrates while in a side-lying position is markedly different from the single swallows that an older child or adult demonstrates while seated in an upright position. Therefore, it does not follow that findings of diagnostic accuracy for assessments of older children and adults should automatically be generalized to the young infant population. To date, there have been no known published studies on diagnostic accuracy for either VFSS or FEES when examining a homogeneous group of bottle-fed infants. As VFSS and FEES are currently considered to be valuable tools for assessing swallowing for a variety of infant populations, the present study sought to determine the diagnostic accuracy of both these instrumental assessments in detecting laryngeal penetration and tracheal aspiration in bottle-fed young infants. Our hypothesis was that both VFSS and FEES would show high degrees of accuracy in detecting penetration and aspiration.

MATERIALS AND METHODS

Patients

The participants in this prospective study were selected from a convenience sample of infants in the neonatal intensive care unit who demonstrated clinical signs of feeding and swallowing difficulties during a bedside clinical assessment. Clinical signs

may have included, but were not limited to, autonomic/physiologic instability, state dysregulation, cough, or refusal to feed. Inclusion criteria included being at least 37 weeks postmenstrual age, being medically stable to undergo both a VFSS and FEES assessment, and not having a bilateral complete cleft lip and palate. This study was approved by the hospital and university Institutional Review Boards to ensure all procedures were ethical and followed institutional guidelines. Parents or guardians were informed of the study and signed a consent form prior to enrollment.

Procedures

Some of the procedures for the present study have been previously published.[16] While the present study used the same participant group and data collection procedure as previously reported, the objective and findings of this study were different. For convenience of the reader, the procedures specific to this study are reported here as well.

After the infants were enrolled in the study, their swallowing during bottle feeding was assessed using both VFSS and FEES. The two instrumental assessments took place within 24 hours of each other, with a block randomization design used to determine order of assessment. Each instrumental assessment was conducted by a speech-language pathologist (SLP) while a neonatal occupational therapist fed the infant. A neonatal nurse was also present at all studies to monitor the infant's vital signs.

VFSS assessments were conducted in the hospital radiology suite using either a Philips (Amsterdam, The Netherlands) or General Electric (Milwaukee, WI, USA) fluoroscopic unit at 30 frames per second. A radiologist was present for all VFSS assessments, and the selection of fluoroscopic unit was based on availability and

radiology staff preference. Infants were swaddled and placed in an elevated sidelying position (right side down; 15–30 degrees elevation) on a firm foam wedge on the table. This position was utilized as it replicated the feeding position used in the NICU for these infants. Any orogastric or nasogastric tubes were kept in place, and fluoroscopy time was limited to a maximum of three minutes per hospital guidelines. Fluoroscopic images were recorded on a medical digital recorder and then stored on a General Electric Centricity picture archiving and communication system in the electronic record.

FEES assessments were conducted within the NICU using an ultra-slim 2.2-mm diameter flexible ENF-XP rhino-laryngofiberscope with an OTV-S190 Visera Elite video processor and Visera Elite xenon light source CLV-S190 from Olympus (Tokyo, Japan). Any orogastric or nasogastric tubes were removed, and infants were swaddled and placed in the feeder's arms in an elevated sidelying position at 20–30 degrees elevation. In order to calm and soothe infants prior to initiating the FEES procedure, 2 mL of oral sucrose (TootSweet 24% Sucrose Solution; Natus Medical, San Carlos, CA, USA) during nonnutritive sucking was administered 2 minutes prior to and during endoscope insertion. No topical anesthesia or decongestants were used. Images were digitally saved to an Image Stream Medical (Littleton, MA, USA) nStream HD G3 channel image capture system.

Both the VFSS and FEES assessments utilized the same set procedure with up to six feeding trials that incorporated changes in bottle type, nipple type, and/or liquid consistency. Six different bottles with 30 mL of fluid in each were prepared and labeled by trial number prior to each feeding assessment. The bottles for FEES assessments also

included two drops (0.1 mL) of McCormick (Sparks, MD, USA) green food-grade dye. Each assessment began with Trial 1 and continued in a systematic manner based on findings of penetration or aspiration. If penetration or aspiration were observed during any trial, the assessment continued to the next trial. Assessments were discontinued if neither penetration nor aspiration were observed or if the infant could not extract a bolus due to fatigue or state dysregulation.

Trial 1: Each infant was initially assessed using a Similac volu-feed nurser with slow-flow nipple (Abbott Nutrition, Lake Forest, IL, USA) and thin consistency. During FEES, infant formula or expressed breastmilk was used. During VFSS, 10 mL of infant formula or expressed breastmilk was combined with 20 mL of Varibar Thin reconstituted barium sulfate (Bracco Diagnostics, Monroe Township, NJ, USA).

Trial 1A: If neither penetration nor aspiration were visualized in Trial 1, the infant was assessed for a second and final trial using a Similac standard-flow nipple with thin consistency.

Trial 2: If the infant penetrated or aspirated during Trial 1, the infant was then assessed using a Similac standard-flow nipple with half-nectar consistency. This consistency was made by adding ¾ tsp of Beech-Nut (Amsterdam, NY, USA) Gently Ground Single Grain Rice Cereal to the 30 mL of thin infant formula for FEES or the thin formula/barium combination for VFSS.

Trial 3: If the infant penetrated or aspirated during Trial 2, the infant was then assessed using a Playtex Ventaire bottle (Playtex Products, North Bergen, NJ, USA) with a medium-flow nipple and nectar consistency (1½ tsp rice cereal added to the thin liquid).

Trial 4: If penetration or aspiration were observed during Trial 3, the infant was then assessed using a Playtex Ventaire bottle with a fast-flow nipple and nectar consistency.

Trial 5: If the infant continued to penetrate or aspirate, the infant was assessed using a Playtex Ventaire bottle with a fast-flow nipple and honey consistency (2¼ tsp rice cereal added to the thin liquid).

After all study participants had completed both instrumental assessments, the deidentified, randomized VFSS and FEES recordings were viewed independently by two SLPs. VFSS recordings were viewed within the electronic record system on a 20" Dell (Round Rock, TX, USA) desktop computer screen; FEES digital recordings were transferred to individual DVDs and viewed on a Dell 15" laptop screen, with the image appearing in a 3" diameter frame. The SLPs were blinded to participant as well as to the total number of trials attempted by each participant; that is, they were unaware of the determination of penetration and aspiration made during the real-time assessment when viewing the recordings.

Each recorded trial was coded for the presence or absence of laryngeal penetration and tracheal aspiration. Laryngeal penetration was coded as present when any liquid was observed within the laryngeal vestibule on or above the vocal folds. Tracheal aspiration was coded as present when liquid was observed entering the trachea, within the trachea, or being expelled from the trachea into the larynx. By definition, each instance of aspiration was also coded as an instance of penetration. During the viewing sessions, the SLPs were given liberty to pause and rewind the recordings within each individual

trial but were required to make a determination as to the presence or absence of penetration and aspiration within a given trial before viewing the next trial or participant.

Since the purpose of this study was to compare the findings of the two instrumental assessments within participants, we sought 100% clinician agreement on the presence and absence of penetration and aspiration for each trial. To obtain this agreement, the SLPs subsequently reviewed and discussed discrepant trials together and reached consensus for all trials.

Data Analysis

Data were analyzed by creating 2 x 2 tables for penetration and aspiration indicating the frequencies of positive (present) and negative (absent) findings for each VFSS and FEES trial, then calculating the agreement between the two instrumental assessments. Additional 2 x 2 tables were developed for penetration and aspiration comparing VFSS and FEES separately against the composite reference standard using the "OR" rule where a finding of penetration or aspiration was considered positive if detected with either VFSS or FEES and negative if not detected at all.[25] Using the composite reference standard allowed us to consider any positive finding as "true" (that is, not allowing for false positives) and to compare the diagnostic accuracy of both VFSS and FEES to this standard.

Cohen's kappa statistic was calculated to provide further indication of reliability.[27] The kappa statistic can range between 0 and 1 and represents the proportion of agreement greater than that expected by chance. Kappa is typically interpreted as .01-.20=slight agreement, .21-.40=fair, .41-.60=moderate, .61-.80=substantial, and .81

to 1=almost perfect.[28] Finally, sensitivities, specificities, positive predictive values, and negative predictive values were calculated from each 2 x 2 table using either the other instrumental assessment or the composite as the reference standard.

RESULTS

A predetermined sample size of 25 infants participated in this study and included 10 males and 15 females. Average postmenstrual age of the infants at time of study enrollment was 39.9 weeks (SD=2.9; Range=37-49). The time between the first and second instrumental assessment ranged from 2 hrs 46 mins to 23 hrs 10 mins (M=14 hrs 30 mins; SD=8 hrs 7 mins). Other demographic and medical characteristics of the participant group are shown in Table 1.[16]

The data were compiled to conduct within-participant comparisons of the same trial (same bottle, nipple, and consistency) between the two instrumental assessments. One infant's VFSS assessment was unable to be reviewed due to technical problems with the recording, and data could not be collected for two infants during FEES assessments due to no bolus extraction from the bottle. Therefore, the data of 22 infants were analyzed for this study. With these 22 infants, there were 50 total instances where individual participants were assessed with the same trial during both VFSS and FEES, allowing for the paired trial comparisons.

Table 2 shows the within-participant agreement between the two assessments, VFSS and FEES, in detecting the presence or absence of penetration and aspiration across all 50 paired trials. There was a 56% overall agreement for penetration and a 92% agreement for aspiration (both assessments agreeing on positive and negative findings).

Kappa values for both penetration and aspiration were fair at best.[28] There were many more instances of penetration detected using FEES compared to VFSS, and there were very few observations of aspiration with either assessment.

Table 3 shows the within-participant agreement for each instrumental assessment when compared to the composite reference standard using the "OR" rule. Rates of agreement ranged from 64% to 98%. Kappa values ranged from fair to almost perfect agreement, with agreement on aspiration between VFSS and the composite reference and agreement on penetration between FEES and the composite reference being the highest.[28]

Table 4 shows the sensitivities, specificities, positive predictive values, and negative predictive values for both VFSS and FEES compared to the other assessment as the reference standard, and Table 5 presents sensitivities and negative predictive values for each assessment compared to the composite reference standard using the "OR" rule. Since the composite reference standard eliminates false positives by considering observations of penetration and aspiration viewed with either assessment as true positives, specificities and positive predictive values would calculate to 100% and therefore are not shown so as not to be misleading. FEES showed higher sensitivity than VFSS for penetration (89% and 49%, respectively) and also had a higher negative predictive value for penetration (79% vs. 45%). Both assessments had high negative predictive values for aspiration.

DISCUSSION

The present study attempted to examine the diagnostic accuracy of both VFSS and FEES in detecting penetration and aspiration in bottle-fed young infants. Each of

these instrumental assessments is an important component of a comprehensive infant feeding and swallowing evaluation, offering different views of the swallowing anatomy and physiology. Since there is no consensus as to which assessment should be considered the "gold standard" against which other assessments should be measured, this prospective study compared VFSS against FEES as the reference standard, FEES against VFSS as the reference standard, and both VFSS and FEES against a composite reference standard using the "OR" rule.[25]

There was only moderate agreement between the two instrumental assessments, VFSS and FEES, in detecting the presence or absence of penetration (56%), with FEES detecting more instances of penetration than VFSS. This result agrees with previous findings that penetration was more easily detected or was categorized as more severe when using FEES compared to VFSS.[13,20-22,29] In the present study, penetration was visualized with FEES and not VFSS in 36% of the paired trials (Table 2). This discrepancy contributed to the lower overall penetration agreement rate between the two assessments but was reflected in the very high rate of agreement between FEES and the composite reference (Table 3) as well as the higher sensitivity values for FEES in both comparison conditions (Tables 4 and 5).

For aspiration, the overall agreement between VFSS and FEES was high (92%), although the vast majority of the trials revealed no instances of aspiration. Unfortunately, there is little data on the prevalence of swallowing disorders in young infants, including rates of aspiration.[30] One study reported that 17.1% of very low birth weight young infants who were suspected of dysphagia aspirated during VFSS,[31] while other studies

that included older infants with suspected dysphagia reported aspiration rates of 21% and 39.3%.[7,32] In our study, 5 of the 25 infants (20%) aspirated at least once during one or both instrumental assessments. However, because we analyzed and reported our data by paired trials, and because subsequent trials were intended to eliminate aspiration, this resulted in only 6 aspiration events being detected out of the 100 total trials (Table 2). Therefore, although our findings suggested that VFSS was more sensitive in detecting aspiration than FEES, this should be interpreted with caution.

Clinically, the ability to better visualize penetration events with FEES may have important implications for young infants in particular. It has been reported that deep laryngeal penetration is highly correlated with aspiration in the pediatric population.[6] In addition, it appears that infants and young children who penetrate and aspirate do so further into their feedings; most do not penetrate or aspirate on the first few swallows and instead demonstrate deterioration of their skills over the course of the feeding.[6-7] FEES allows for observation of a longer feeding, with the infants being held in a more natural feeding position and drinking the actual breastmilk or formula they consume during typical feedings. It also has the advantage of no radiation exposure. If clinicians can diagnose a swallowing disorder based on the presence or absence of penetration events and use that information to develop appropriate feeding plans, FEES may be a practical alternative to VFSS. It is clear that further research is needed in this area.

One possible limitation of the present study was the use of existing clinical equipment, specifically two different fluoroscopy units for VFSS and a fiberscope for FEES, as the study was conducted in a hospital and not a laboratory setting. At the same

time, the recordings were able to be viewed and coded by the clinicians, and the use of existing equipment adds ecological validity to the study. Another limitation is the fact that the instrumental assessments were not conducted simultaneously but rather hours apart. We attempted to control for this by conducting the assessments within 24 hours of each other, yet we do acknowledge that differences in infant swallowing between the two assessments could be due to changes in the infant's swallow over time or in the variations inherent in the assessments themselves. A third limitation is the small number of participants. While our findings are intriguing, more studies should be conducted with larger numbers of participants.

A strength of this study is the use of the composite standard as the reference standard. Use of this composite standard accepts that any observation of penetration or aspiration is "true" and therefore disallows false positives. It seems unlikely that, within our study, two experienced clinicians would agree on a positive finding when one did not truly exist. We would also argue that clinically, direct observation of penetration or aspiration with either instrumental assessment indicates a true positive. Therefore, we advocate that the use of the composite standard should be the accepted "gold standard" when attempting to determine diagnostic accuracy of either instrumental assessment.[25] In our study, sensitivity for both VFSS and FEES was higher for detecting penetration and aspiration when compared to the composite reference standard rather than the other instrumental assessment. Because VFSS and FEES offer completely different views of the swallowing mechanism, each may be used to identify penetration or aspiration in certain situations when the other instrumental assessment cannot.[33]

Deciding which instrumental assessment to use in a comprehensive feeding evaluation depends on a variety of factors and includes more than just the ability to detect penetration and aspiration. Our team has access to both VFSS and FEES as well as clinicians who are skilled in their use and interpretation, allowing us to select the most appropriate assessment for each individual infant. A neonatal feeding therapist (speech-language pathologist or occupational therapist) conducts an initial bedside assessment on an infant who is demonstrating feeding difficulty, then consults with the neonatologist and bedside nurse on the results of the assessment. Compensatory feeding strategies such as pacing or changes in positioning or feeding equipment are attempted initially. If the infant continues to demonstrate feeding difficulties and the team determines an instrumental assessment is warranted, we typically select FEES as the first instrumental assessment in the NICU because of the more natural feeding environment, use of breastmilk and/or formula, and the ability to assess swallow function and the impact of therapeutic strategies throughout the course of the feeding.

FEES is useful for infants who demonstrate suck-swallow-breathe incoordination, especially when fatigue is impacting the overall feeding performance, as it allows clinicians to visualize the pharynx and larynx and to evaluate airway protection throughout an entire feeding. For infants who exhibit stridor, stertor, poor cry quality, or other respiratory/airway symptoms that appear to be impacting swallow function, FEES becomes a beneficial multidisciplinary examination in consultation with the otolaryngologist. We generally prefer VFSS when seeking to evaluate the physiologic components associated with an oral phase dysfunction in infants with abnormal or poor

lip and tongue movements or dysfunctional nutritive sucking patterns, since VFSS provides views of the oral cavity whereas FEES does not. VFSS is also preferred for infants with craniofacial anomalies and infants with poor state control, difficulty with self-calming/consoling, and irritability with feedings.

There are specific cases where both instrumental assessments are utilized to obtain as much information as possible to create a safe and effective feeding plan. Some infants with co-morbidities impacting multiple systems such as neurologic, cardiac, and/or respiratory systems will exhibit oral phase dysfunction as well as airway anomalies and poor suck-swallow-breathe coordination. In order to best visualize and assess all three of these areas, both VFSS and FEES are included in the comprehensive feeding evaluation.

CONCLUSIONS

The results of the current study suggest that both VFSS and FEES are valid assessment tools in the comprehensive evaluation of feeding and swallowing in the bottle-fed young infant. FEES appears to allow for better detection of penetration than VFSS and has a higher negative predictive value. Because of the low prevalence of aspiration in this study, we are unable to draw conclusions about either assessment's diagnostic accuracy for aspiration. Use of both instrumental assessments may lead to increased diagnostic accuracy of swallowing disorders in young infants.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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Table 1. Demographic and medical characteristics of the 25 study participants

Characteristic	*Value*[1]
Gestational age at birth (weeks)	28.7 ± 4.8 (23–39)
Birth weight (grams)	1234 ± 746 (460–3105)
Days since birth	79.2 ± 33.8 (9–131)
Patent ductus arteriosus ligation	4 (16%)
Intraventricular hemorrhage	8 (32%)[2]
Grade 1	1 (4%)
Grade 2	5 (20%)
Grade 3	7 (28%)
Grade 4	2 (8%)
Surgical necrotizing enterocolitis	1 (4%)
Respiratory distress syndrome	19 (76%)
Gastroesophageal reflux disease	4 (16%)
Nasogastric tube	22 (88%)
Oxygen nasal cannula	16 (64%)

[1]Data are presented as mean ± standard deviation (range) or n (%).

[2]Seven of the eight infants had bilateral intraventricular hemorrhage.

Table 2. Agreement between VFSS and FEES in detecting the presence or absence of penetration and aspiration across all 50 paired trials

	Total Agreement (sum (a) and (b)) n (%)	*Kappa*	*(a) Both VFSS and FEES Positive n (%)*	*(b) Both VFSS and FEES Negative n (%)*	*(c) VFSS Positive/ FEES Negative n (%)*	*(d) FEES Positive/ VFSS Negative n (%)*
Penetration	28 (56%)	0.18 (p=.1303)	13 (26%)	15 (30%)	4 (8%)	18 (36%)
Aspiration	46 (92%)	0.30 (p<.05)	1 (2%)	45 (90%)	3 (6%)	1 (2%)

Abbreviations: VFSS, videofluoroscopic swallowing study; FEES, fiberoptic endoscopic evaluation of swallowing.

Table 3. Agreement between VFSS/FEES and the "OR" composite reference standard in detecting penetration and aspiration across all 50 paired trials

	Total Agreement between the Instrumental Assessment and the Composite Standard (sum (a) and (b)) n (%)	*Kappa*	*(a) Both Instrumental Assessment and Composite Standard Positive n (%)*	*(b) Both Instrumental Assessment and Composite Standard Negative n (%)*	*(c) Composite Standard Positive and Instrumental Assessment Negative n (%)*
VFSS					
Penetration	32 (64%)	.36 (p<.001)	17 (34%)	15 (30%)	18 (36%)
Aspiration	49 (98%)	.88 (p<.0001)	4 (8%)	45 (90%)	1 (2%)
FEES					
Penetration	46 (92%)	.82 (p<.0001)	31 (62%)	15 (30%)	4 (8%)
Aspiration	47 (94%)	.55 (p<.0001)	2 (4%)	45 (90%)	3 (6%)

Abbreviations: VFSS, videofluoroscopic swallowing study; FEES, fiberoptic endoscopic evaluation of swallowing.

Table 4. Sensitivity, specificity, positive predictive and negative predictive values for VFSS and FEES using the other assessment as the reference standard

	Sensitivity	*Specificity*	*PPV*	*NPV*
Of VFSS using FEES as the standard				
Penetration	42%	79%	76%	45%
Aspiration	50%	94%	25%	98%
Of FEES using VFSS as the standard				
Penetration	76%	45%	42%	79%
Aspiration	25%	98%	50%	94%

Abbreviations: VFSS, videofluoroscopic swallowing study; FEES, fiberoptic endoscopic evaluation of swallowing.

Table 5. Sensitivity and negative predictive values for VFSS and FEES using the composite as the reference standard

	Sensitivity	*NPV*
VFSS		
Penetration	49%	45%
Aspiration	80%	98%
FEES		
Penetration	89%	79%
Aspiration	40%	94%

Note: Because using the composite reference standard eliminates false positives, specificity and positive predictive values are not reported. Abbreviations: VFSS, videofluoroscopic swallowing study; FEES, fiberoptic endoscopic evaluation of swallowing.