Using fiberoptic endoscopic evaluation of swallowing to detect laryngeal penetration and aspiration in infants in the neonatal intensive care unit

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ABSTRACT

Objective: To evaluate the safety of fiberoptic endoscopic evaluation of swallowing (FEES) and the reliability of both FEES and a videofluoroscopic swallowing study (VFSS) in identifying laryngeal penetration and tracheal aspiration in infants under 3 months old in the neonatal intensive care unit (NICU).

Study Design: Twenty-five infants at least 37 weeks postmenstrual age suspected of aspirating were assessed with FEES and VFSS. Complications, autonomic instability, and vital signs prior to endoscope insertion and following FEES were documented. Blinded video recordings were coded by two reviewers to determine reliability.

Result: We found no major complications or significant differences between FEES prefeeding and postfeeding vital signs, including respiratory rate, heart rate, or oxygen saturation. FEES interrater reliability was 80% for both penetration and aspiration, compared with 87% and 90%, respectively, for VFSS.

Conclusion: FEES is safe and reliable in assessing laryngeal penetration and tracheal aspiration in NICU infants.

INTRODUCTION

Learning how to bottle feed or breastfeed is critical and complex for the newborn. The prevalence of feeding disorders in the pediatric population ranges from 25% to 45% in typically developing children and up to 80% in children with developmental disabilities.[1,2] Preterm infants, sick term infants, and late preterm infants are at greater risk for feeding disorders. Feeding difficulties in these populations can negatively impact growth and development.[3]

For infants in the neonatal intensive care unit (NICU) who experience feeding difficulties, a collaborative, multidisciplinary approach is needed to effectively evaluate feeding and swallowing and to intervene appropriately.[4] Currently, the most common evaluative approach is an observational clinical feeding and swallowing examination followed by a videofluoroscopic swallowing study (VFSS) if warranted. While VFSS is often used, the reliability of this technique to detect laryngeal penetration (material entering the laryngeal vestibule) or tracheal aspiration (material entering the trachea below the vocal folds) in young bottle-fed infants has not been reported. The reliability of VFSS in detecting penetration and aspiration in adults and children ranges from fair to excellent.[5–17] VFSS also has significant limitations for the NICU infant, including transportation to radiology, radiation exposure, the use of barium, limited time for evaluation, and nonphysiological feeding position.[4,18,19] Unfortunately, this means that clinical decisions are made based on an unnatural feeding situation rather than the infant's actual feeding experience. This could lead to unnecessary feeding restrictions, including gastric tube placement.

Fiberoptic endoscopic evaluation of swallowing (FEES) was introduced in 1988 as an instrumental test to examine swallowing in adults.[20] This procedure, which can be done at the bedside while the patient consumes a typical meal, involves inserting a small flexible endoscope

transnasally to view the pharyngeal and laryngeal structures and function. FEES has been reported to be safe[21–23] and reliable (comparable to VFSS)[13,24–26] in detecting laryngeal penetration and tracheal aspiration in adult patients.

FEES has been used in the pediatric population for over 20 years.[27] Since that time, several studies have reported that FEES is safe and reliable in detecting penetration and aspiration in children.[10,19,28–31] While FEES is a more invasive procedure, the advantages of using FEES over VFSS in assessing swallowing in the pediatric population have been widely reported in the literature and include being able to assess an entire feeding at the bedside with the patient in a typical feeding position, having a direct view of the anatomical structures, using real food and liquid, and having the ability to repeat the assessment as often as needed.[4,10,18,19,32]

While some previous pediatric FEES studies have included infants under 12 months old among their participants,[10,19,28,30–32] no study to date has reported on the safety or reliability of using FEES to assess laryngeal penetration or tracheal aspiration exclusively in infants under 3 months. The present study (1) evaluated the safety of FEES with young infants in the NICU and (2) examined the ability of clinicians to reliably identify laryngeal penetration and tracheal aspiration using FEES while observing bottle feeding in these young NICU infants.

MATERIALS AND METHODS

Patients

Inpatient NICU infants were eligible to enroll in the study if they were at least 37 weeks postmenstrual age, demonstrated clinical signs of tracheal aspiration during a bedside feeding and swallowing assessment, were medically stable enough to undergo both a VFSS and FEES assessment, and did not have a bilateral complete cleft lip and palate. A sample size of 25 infants was planned based on time and financial resources. This study was approved by the institutional

review boards of both Baylor University Medical Center and Texas Woman's University 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.

Equipment and Materials

VFSS assessments were conducted in the hospital radiology suite using either a Philips (Amsterdam, The Netherlands) or a General Electric (Milwaukee, WI, USA) fluoroscopic unit. The selection of unit was based on availability, and the images captured were comparable. 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. All recorded images were reviewed on a 20" Dell (Round Rock, TX, USA) desktop computer screen.

FEES assessments were conducted in 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). Images were digitally saved to an Image Stream Medical (Littleton, MA, USA) nStream HD G3 channel image capture system. The images were then transferred to DVD and reviewed on a Dell 15" laptop screen, appearing in a 3" diameter frame.

Procedures

After parents or guardians had given informed consent and the infant was enrolled in the study, each infant was randomized as to which assessment, VFSS or FEES, would occur first using a block randomization to ensure equal distribution of the order. Randomization labels were prepared in advance of the study, and researchers were blind to order of assessment until after the infant was enrolled. The second assessment occurred within 24 hours of the first. All

assessments were conducted by licensed and certified speech-language pathologists (SLPs) who met facility-developed clinical competency standards for conducting infant VFSS and FEES assessments. A radiologist was present during all VFSS assessments, and a neonatal occupational therapist fed the infant during all VFSS and FEES assessments.[4]

For each assessment, the SLP followed a standard protocol, which required each infant to begin with a Similac slow-flow nipple (Abbott Nutrition, Lake Forest, IL, USA) and thin consistency. Subsequent nipple types and consistencies were presented based on the infant's response to the initial bottle (Table 1). Assessments were terminated if the infant was unable to extract the bolus, when the SLP determined the infant was safe on a given consistency and nipple combination, or when all trials had been completed.

For FEES assessments, infant formula or expressed breastmilk was used for the thin consistency. For VFSS assessments, 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). For both VFSS and FEES, Beech-Nut (Amsterdam, NY, USA) Gently Ground Single Grain Rice Cereal was used to thicken the formula (or formula-barium mix), using ¾ tsp per 30 mL for half-nectar, 1½ tsp per 30 mL for nectar, and 2¼ tsp per 30 mL for honey consistencies. Breastmilk was only used for thin consistency and not thickened with rice cereal. (The protocol for determining these consistencies is facility-specific as no standard guidelines are currently in place.[33]) In order to better visualize the liquid during FEES, two drops (0.1 mL) of McCormick (Sparks, MD, USA) green food-grade dye were added to each 30 mL bottle.[34]

During VFSS assessments, infants were swaddled and placed in an elevated sidelying position (right side down; 15–30 degrees elevation) on a foam wedge placed on the table and

were limited to 3 minutes of fluoroscopy for the assessment. For FEES, infants were swaddled and placed in the feeder's arms in an elevated sidelying position at 20–30 degrees elevation and were permitted to complete the feeding as tolerated and/or until a safe, functional feeding plan was determined. Orogastric and nasogastric tubes, if any, were removed prior to endoscope insertion. In order to calm and soothe infants in anticipation of a potentially distressing procedure, 2 mL of oral sucrose (TootSweet 24% Sucrose Solution; Natus Medical, San Carlos, CA, USA) in conjunction with nonnutritive sucking was administered 2 minutes prior to and during endoscope insertion. No topical anesthesia or decongestant was used on the infants.

The safety of FEES was evaluated by observing and documenting whether any complications (e.g., epistaxis or laryngospasm) or major instances of autonomic instability occurred during the procedure. A major instance of autonomic instability was defined as any episode of dyspnea, apnea, tachypnea, cyanosis, and/or bradycardia/tachycardia that required bag-valve mask ventilation. In addition, the infants' vital signs were assessed before, during, and after FEES examinations. Each infant's respiratory rate, heart rate, and oxygen saturation levels were recorded within 10 minutes before endoscope insertion and within 5 minutes following the end of the feeding assessment.

Following completion of all participant assessments, the digital VFSS and FEES recordings were randomized for viewing by two SLPs. The SLPs were blinded to participant and to the number of trials attempted by each participant. They were permitted to pause and rewind the recordings within each trial but were required to make a determination as to the presence or absence of laryngeal penetration (liquid within the laryngeal vestibule above the vocal folds) and tracheal aspiration (liquid below the vocal folds) within a given trial before viewing subsequent trials/participants. By definition, instances of aspiration also included penetration.

RESULTS

Twenty-five infants were enrolled in the study between January and October 2014 and participated in both VFSS and FEES procedures. Thirteen infants were randomly assigned to receive VFSS as the first study, and 12 were assigned to receive FEES first. Most of the 25 infants were female (10 males; 15 females), with 80% white and 20% African American (24% of Hispanic/Latino ethnicity). Postmenstrual age at enrollment ranged from 37 to 49 weeks (M = 39.9; SD = 2.9). More than half the infants (64%) were on low-flow supplemental oxygen via nasal cannula at the time of the procedures; the rest were on room air. Oxygen flow ranged from 0.1 to 1.0 L/min for infants at the time of the FEES procedure and from 0.3 to 0.8 L/min at the time of the VFSS procedure. The percentage of oxygen administered via nasal cannula ranged from 29% to 100% during the FEES procedure (done at the bedside in the NICU) and was 100% during VFSS because of the oxygen tank used for the transport to radiology. Table 2 provides additional information on participants' demographic and medical characteristics.

No adverse events or major complications (e.g., epistaxis or laryngospasm) occurred during the study. No infant demonstrated any instance of autonomic instability such as dyspnea, apnea, tachypnea, cyanosis, and/or bradycardia/tachycardia that required bag-valve mask ventilation. In addition, there were no significant differences between the prefeeding and postfeeding vital signs of respiratory rate, heart rate, and oxygen saturation levels (Table 3).

Due to technical problems with one of the recordings, one infant VFSS assessment could not be reviewed. In addition, swallowing data could not be collected for two infants during FEES assessments due to no bolus extraction.

Table 4 shows the interrater agreement percentages and kappa coefficients for penetration and aspiration across all consistency and bottle trials for VFSS and FEES. High interrater

agreement was obtained for penetration with both VFSS (87%) and FEES (80%), as well as for aspiration with both VFSS (90%) and FEES (80%). Kappa values were higher for agreement on penetration than they were for aspiration for both VFSS and FEES. Rater agreement was further analyzed by examining the degree to which the reviewers agreed on positive ratings (i.e., the presence of either penetration or aspiration) and negative ratings (i.e., the absence of either penetration or aspiration). Reviewers had high rates of agreement for detecting both the presence and absence of penetration using VFSS (86% and 88%, respectively) and FEES (85% and 72%, respectively). Reviewers also had high rates of agreement for detecting the absence of aspiration for both VFSS (94%) and FEES (89%). However, low rates of agreement were seen for detecting the presence of aspiration for both VFSS (43%) and FEES (0%).

DISCUSSION

FEES is recognized as safe and reliable for diagnosing laryngeal penetration and tracheal aspiration in the adult and pediatric populations. The present study demonstrated that FEES is also safe and reliable for evaluating penetration and aspiration in young infants in the NICU and should be considered as an option for instrumental feeding assessment in this population.

Establishing the safety of FEES in the newborn and young infant population is crucial. A few studies included some infants as a subset of participants in their pediatric FEES research but did not specifically report on the safety of FEES within this population.[10,29–32] The one study that did examine the safety of FEES in infants included older infants up to 10 months old.[19] With this wider age range of infants, FEES was reported to be safe, with no infant demonstrating major complications or significant changes in vital signs.

Similarly, the young infants in the present study (no older than 9 weeks adjusted age) had no major adverse reactions during FEES. One infant's oxygen saturation level was as low as

52% following a 10-minute FEES feeding session up through honey consistency with multiple instances of penetration. This infant, who was already receiving oxygen, recovered easily with blow-by oxygen. No other infant's oxygen level went below 86% following a FEES feeding. Some infants in this study demonstrated minimal irritability during the initial placement of the scope, which was eliminated when the neonatal therapist provided neurobehavioral support through swaddling, containment, sucrose administration with nonnutritive suck, and environmental modifications including sound and light reduction. Of the 25 infants examined using FEES, only 2 were unable to calm after placement of the scope in order to initiate feeding. However, the anatomy of the airway and secretion management could be assessed with those infants, providing further diagnostic information for developing a feeding plan.

Interrater reliability was good for both VFSS and FEES in observing penetration and aspiration in the bottle-fed young infants. Kappa values ranged from moderate to substantial for detecting penetration and from zero to fair for detecting aspiration. It is important to note that the kappa statistic is influenced by the prevalence of the finding. With the relatively few instances of aspiration noted on both VFSS (14% of all trials) and FEES (20% of all trials), the low kappa values may not necessarily reflect poor overall agreement.[35] At the same time, these rates of agreement for young infants were consistent with other published findings for VFSS and FEES for both adults[13,15,16] and children,[10,30] lending support for these results. The area of greatest disagreement between raters was in detecting the presence of aspiration, and this occurred during both VFSS and FEES examinations. Since previous researchers have not reported reliability findings in this manner, this area warrants further study.

The use of FEES during a comprehensive feeding evaluation adds more information for the neonatologist and the rest of the feeding team to make the most appropriate clinical decisions

for the infant. Unlike VFSS, FEES allows the clinician to visualize the pharyngeal and laryngeal anatomy and assess secretion management. Moreover, the clinician can observe bolus flow and movement through the hypopharynx and larynx as well as localize residual material. In the present study, use of FEES prompted immediate referrals to specialty physicians for several infants, which resulted in diagnoses of laryngomalacia, tracheomalacia, vocal cord paresis/paralysis, and gastroesophageal reflux.

Performing a FEES assessment in the NICU also allows the clinician and infant to experience a more natural feeding evaluation with the ability to modify the environment, manipulate the position of the infant to assess changes in swallowing, and attempt therapeutic/compensatory strategies over the course of the entire feeding. In addition, the family can participate in and observe the evaluation and feeding, with parent education being provided in real time. Use of FEES also allows for assessment of the swallow with the infant's true diet. Formula or expressed breastmilk are used and thickened if warranted. With VFSS, barium must be included, raising concerns that the barium mixture deemed "safe" for the infants is not comparable to the actual formula or breastmilk the infants will be consuming.[36,37]

There are a few limitations to this study. While all the participants were bottle-feeding infants under 3 months old, making the findings easier to generalize, the sample size was nevertheless small. In determining reliability, the raters were not permitted to confer in order to reach consensus, a method that has been shown to increase interrater reliability.[9,11] Finally, the quality of the recorded images may have been a factor. The magnification of the images during VFSS assessments varied depending on the radiologist conducting the study; therefore, the VFSS recordings were not consistent in quality across the study. Unfortunately, this is a common issue in clinical settings. In addition, FEES assessments were completed with existing clinical

equipment using a fiberscope and were not recorded in high definition. While the anatomical structures and pharyngeal phase of swallowing could be visualized, the image quality may have impacted the raters' ability to more reliably identify penetration and aspiration. Future research using a high-definition videoscope may result in greater reliability for identifying both penetration and aspiration in this population.

CONCLUSION

This study suggests that FEES has a place in the NICU as part of a comprehensive feeding and swallowing evaluation and management program. It was found to be safe and reliable in detecting laryngeal penetration and tracheal aspiration in bottle-fed infants under 3 months of age who demonstrated difficulty during a clinical feeding evaluation.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Table 1. Nipple and bottle trial protocol for neonatal dysphagia assessment

			Results for penetration/aspiration	
Trial	*Consistency*	*Nipple*	*Positive*	*Negative*
1	Thin liquid	Abbott gold rim (slow-flow nipple)	Continue to Trial 2	Proceed with thin liquid and Abbott clear rim (standard nipple) with assessment of swallowing function with least restrictive means. Discontinue study and establish feeding plan.
2	Half nectar	Abbott clear rim, standard nipple	Continue to Trial 3	Discontinue study
3	Nectar	Playtex Ventaire bottle, medium-flow nipple	Continue to Trial 5	Proceed to Trial 4
4	Nectar	Playtex Ventaire bottle, fast-flow nipple	Continue to Trial 5	Discontinue study
5	Honey	Playtex Ventaire bottle, fast-flow nipple	Continue to Trial 6	Discontinue study
6	Puree	Spoon	Discontinue study and establish feeding plan.	

Table 2. 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 3. Vital signs of 25 young infants before and after feeding with fiberoptic endoscopic evaluation of swallowing

	Before feeding		*After feeding*		
Vital signs	*Mean (SD)*	*Range*	*Mean (SD)*	*Range*	*P*
Respiratory rate (breaths/minute)	52.7 (10.8)	31–78	50.8 (18.9)	21–107	0.62
Heart rate (beats/minute)	163 (14)	128–184	168 (15)	130–188	0.11
Oxygen saturation (%)	97.5 (2.6)	92–100	95.1 (9.6)	52–100	0.22

Table 4. Interrater reliability for penetration and aspiration across consistency and bottle trials with VFSS and FEES

		Penetration			*Aspiration*		
Assessment	*n*	*Agreement*	*Kappa*	*P*	*Agreement*	*Kappa*	*P*
VFSS	78	87%	0.74	<0.0001	90%	0.39	<0.0001
FEES	66	80%	0.57	<0.0001	80%	–0.03	0.63

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