Comparison of clinical and videofluoroscopic evaluation of children with feeding and swallowing difficulties

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The objectives of this study were threefold: (1) to evaluate the accuracy of clinical evaluation compared with videofluoroscopic swallowing studies (VFSSs) in the detection of penetration and aspiration in children of age 0 to 15 years presenting with feeding and swallowing problems; (2) to assess the relationship between therapists' confidence ratings in making judgements about the presence or absence of penetration and aspiration, and the accuracy of their evaluation as confirmed by VFSSs; (3) to identify clinical predictors of penetration and aspiration during clinical evaluation of children with feeding and swallowing difficulties. We used a prospective study to evaluate the sensitivity, specificity, and positive and negative predictive values of a diagnostic clinical evaluation compared with VFSSs (criterion standard). Clinical evaluation and videofluoroscopy forms for oral motor and swallowing evaluation, which included potential indicators of aspiration, were designed for this project. Seventy-five children with feeding problems participated (33 females, 42 males; age range 0 to 14 years, mean 2 years; 62% of participants younger than 12 months). For fluids, clinical evaluation showed a sensitivity of 92% for aspiration. For solids, sensitivity for detecting aspiration was 33%. Analysis of the therapists' mean confidence ratings compared with the accuracy of their judgement demonstrated that when therapists were very sure that the child was aspirating or penetrating or not, they were correct. When the therapists were unsure, then the accuracy of prediction was not as good. Cough was the most significant predictor ($p<0.05$) of fluid aspiration and penetration. We conclude that clinical evaluation with experienced clinicians can detect aspiration and penetration of fluids in children of varied ages and diagnoses, but that it is not accurate with solids.

Many children who are referred for feeding and swallowing assessment undergo both clinical evaluation and a videofluoroscopic swallowing study (VFSS), particularly when aspiration and penetration are suspected. These conditions are of utmost concern as they can compromise the health of the child. In the assessment and discussion of dysphagia (i.e. swallowing problems), it is important to understand the difference between aspiration and penetration. Aspiration occurs when liquid or food enters the airway and travels below the level of the vocal cords towards the lungs. Penetration occurs when liquid or food enters the airway, but does not travel below the level of the vocal cords (Rosenbek et al. 1996, Brodsky 1997).

Clinical evaluation includes the assessment of many components of the feeding process: oral motor function (i.e. oral preparatory and oral stages of swallowing), muscle tone, posture, sensory response, feeding behaviour, self-feeding ability, parent–child interaction, social and environmental components, and overall physical and developmental abilities. Medical, developmental, and feeding histories are important variables in a comprehensive clinical evaluation (Logemann et al. 1999). Clinical evaluation is necessary for determining comprehensive feeding strategies and recommendations (Bacon and Smith 1994, Sheckman and Manno 1996). However, clinical evaluation may fail to detect penetration or aspiration and is not able to assess accurately the pharyngeal and oesophageal stages of swallowing (Linden 1989, Zerilli et al. 1990, Groher 1994, Zenner et al. 1995, Wright et al. 1996, Leder 1997). Clinical assessment can be conducted in a more natural manner with children, and is an essential tool for therapists, especially those who do not have access to VFSS.

VFSSs are videotaped X-rays that show how food passes from the mouth through the pharynx. VFSS is commonly recommended and accepted as the criterion standard for evaluating the unseen pharyngeal and oesophageal stages of swallowing and the presence of aspiration or penetration (Lazarus and Logeman 1987, Palmar et al. 1993, Gibson et al. 1995, Wilcox et al. 1996, Lefton-Greif and Arvedson 1997). However, VFSSs expose children to radiation, are expensive, and resource intensive. They provide only a brief sample of swallowing performance, and can be an unpleasant experience and frightening for some children. It is often presented that fibre-optic endoscopic evaluation of swallowing (FEES) is the real criterion standard as it allows for direct visualization of the hypopharynx and larynx during swallowing (Lefton-Greif and Loughlin 1996, Leder et al. 1998, Thompson Link et al. 2000). However, this technique is quite invasive as it requires insertion of a flexible nasopharyngoscope, and infants and children often require restraint during this procedure. It is not used regularly in our setting for this reason. Therefore, it was not considered feasible for this study. Other methods being used to detect aspiration and penetration are cervical auscultation and pulse oximetry but, so far, neither has been proven to challenge the criterion standard of visualizing the anatomical structures during swallowing available through VFSS and FEES.

VFSS is not readily available to all clinicians who are assessing children. In contrast, when it is available, it is often used with increasing frequency. This has led some authors to query the overuse of VFSS and to examine the cost–benefit of the procedure in the evaluation of swallowing problems (Mari et al. 1997, Logemann et al. 1999).

Many authors have attempted to examine the issues of clinical evaluation compared with VFSS. Although Ott (1996) found high agreement between clinical and videofluoroscopic evaluation, the results must be regarded with caution because of weak research methods including sample bias and lack of reported statistical analysis (Leder 1997). Splaingard et al. (1988) indicated that clinical evaluation underestimates the presence of aspiration in a primarily adult population with neurological dysfunction. In a retrospective chart review, Zerilli et al. (1990) suggested that VFSS is an important addition to the evaluation process of children. A retrospective chart review of 85 dysphagia assessments in a population over 65 years of age by Krefting and colleagues, agreed with previous literature concluding that VFSS focuses on aspects of swallowing that cannot be evaluated clinically and that coughing was not indicative of aspiration (Sorin et al. 1988, Splaingard et al. 1988, Krefting et al. 1990). Some authors have examined predictors of aspiration and penetration both in VFSS and in clinical evaluation in adult populations with a variety of different findings (Linden 1989, Perlman et al. 1994, Murray et al. 1996, Rosenbek et al. 1996, Mari et al. 1997, Logemann et al. 1999). Overall there is a paucity of research in the area of paediatric dysphagia. The evidence using adult populations cannot be generalized to children.

It is important to examine the relationship between clinical evaluations and VFSS in the evaluation of children. There are advantages and disadvantages to both clinical evaluation and VFSS, but either may not always be available and both may not always be needed. This paper acknowledges that both types of evaluation are invaluable in the evaluation of the child with a feeding and swallowing problem (dysphagia). Indicators have not been established as to when VFSS is a necessary and important addition to clinical evaluation for dysphagia in children. Therefore, VFSSs may be overused with children who do not require them. Conversely, children who require it may not receive this evaluation. There are times when only a clinical evaluation is necessary or available and it is, therefore, important to determine the accuracy of clinicians when evaluating aspiration and penetration.

The purpose of the study was to determine when only clinical evaluation is necessary and when VFSS is an important and necessary addition to the evaluation process to guide clinical decision-making and ensure the delivery of safe, efficient, cost-effective, and quality care of children.

The study objectives were: (1) to evaluate the accuracy of the clinical evaluation compared with VFSS in the detection of penetration and aspiration in children aged 0 to 15 years; (2) to assess the relationship between therapists' confidence ratings in making judgements about the presence or absence of penetration and aspiration, and the accuracy of their judgements as confirmed by VFSS; (3) to identify clinical predictors of penetration and aspiration during clinical evaluation of children with feeding and swallowing difficulties.

Method

The hospital and university ethics committee approved the study. Informed consent was obtained from parents or guardians.

PARTICIPANTS

Infants and children referred to the Feeding and Swallowing Service were consecutively recruited over a 15-month period. McMaster Children's Hospital at Hamilton Health Sciences is a tertiary care centre with a referral base and catchment area of central southwest Ontario. It is affiliated with the Faculty of Health Sciences, McMaster University. Eligible children included in-patients and outpatients, with any diagnosis, ages 0 to 15 years presenting with feeding and/or swallowing difficulties. Children had to undergo both clinical and VFSS evaluations to be included in the study.

STUDY DESIGN

This was a prospective study to evaluate the sensitivity, specificity, and positive and negative predictive values of a diagnostic test. The clinical evaluation by occupational therapists was compared with the criterion standard of VFSS in evaluating whether or not a child was aspirating or penetrating during oral feeding.

PROCEDURE

The child's referral for feeding assessment was discussed by the team following standard clinical procedures. Decisions whether to include VFSS and clinical evaluation were made and then consent was obtained. A child was first assessed clinically by the occupational therapist. VFSS was done after clinical assessment on the same day or within 48 hours if the team felt that VFSS was required.

Five occupational therapists and one speech-language pathologist were involved in the intake, clinical assessment, and VFSS of the children. For each child, a therapist (different

Table I: Reason for referral and types of diagnosis

Reason for referral	*Number (n=75)*	*Types of diagnosis*
Gastro-oesophageal reflux vomiting	13	Cerebral palsy, prematurity, Pierre Robin sequence,
Behaviour/aversive reactions	9	hypoxic–ischemic encephalopathy, Vacterl syndrome,
Failure to thrive/poor intake	9	Angelman syndrome, infantile spasms, cardiac condition
Respiratory symptoms and cough	8	Down syndrome, developmental delay, seizure disorder,
Sensory/texture issues	8	failure to thrive, acquired brain injury, brain tumour
Oral motor coordination and feeding difficulties	7	
Swallowing difficulties	5	
Choking	5	
Query aspiration	5	
Other	6	

from the VFSS therapist) completed the clinical evaluation. An 'experienced clinician' was defined as an occupational therapist or speech and language pathologist with at least 5 years' experience of working with infants and children with feeding and swallowing problems. The therapists' experience ranged from 5 to 25 years in paediatrics with postgraduate training in the assessment and management of oral motor/swallowing problems. All therapists underwent consistency training with the evaluation tools during a pilot study before the start of the study.

Clinical assessment procedure

A clinical evaluation form for oral motor and swallowing evaluation (Appendix I) was designed for therapists to record their findings. It included variables suggested in the literature as indicators of aspiration (Linden et al. 1993, Perlman et al. 1994, Lefton-Greif and Loughlin 1996, Rosenbek et al. 1996, Putman 1997, Smith et al. 1999). The evaluation was based on the typical clinical evaluations as performed by clinicians at the hospital and according to the theory of dysphagia evaluation (Wolf and Glass 1992, Logemann 1995, Arvedson and Lefton-Greif 1998, Breton et al. 1999). Upon completion of the clinical evaluation, therapists indicated their level of confidence about their suspicions of penetration and aspiration by using a confidence rating scale expressed in percentages.

Every effort was made to recreate the typical feeding experience for that child. To that end, the child was fed by his/her caregiver, in their preferred feeding position using the child's own foods and feeding utensils. Fluids and solids were used for evaluation when developmentally appropriate and as tolerated by the child.

Videofluoroscopy procedure

The evaluation was completed on a remote control GE Prestilix fluoroscopy unit, and recorded on a VHS Panasonic video recorder interfaced directly with the radiologic equipment. Most studies were conducted using lateral projection views only. Every effort was made to conduct the study in a feeding position typical for the child being assessed. Infants and children were fed in either their own seating system or placed into as similar a position as possible using radiology chairs, and adapted tumbleform seats. The child's own foods were used, combined with pre-mixed liquid barium and/or powdered barium. For liquid evaluation, pre-mixed liquid barium consistencies of 100, 250, 800, and 2000 counts per second (centipoise) were used to provide standardized measures for accurate comparisons. Commercially prepared non-ionic X-ray contrast solutions (Nycomed Omnipaque 240 and Mallinckrod Medical Hexabrix) were used for the infant feeds. Each child was fed by his or her typical caregiver, or by the occupational therapist. An occupational therapist or speech language pathologist different from the clinical evaluator completed VFSS evaluation. To address the concern in the literature over the poor reliability found in the evaluation of VFSS (Gibson et al. 1995, Wilcox et al. 1996), our VFSS evaluation was discussed with the radiologist in attendance and consensus scores were used to support the accuracy and improve the validity of our VFSS findings.

The VFSS evaluation form used for videofluoroscopy evaluation (Appendix II) was similar to the clinical assessment form, with the addition of laryngeal and pharyngeal components of swallowing observable only under radiological examination.

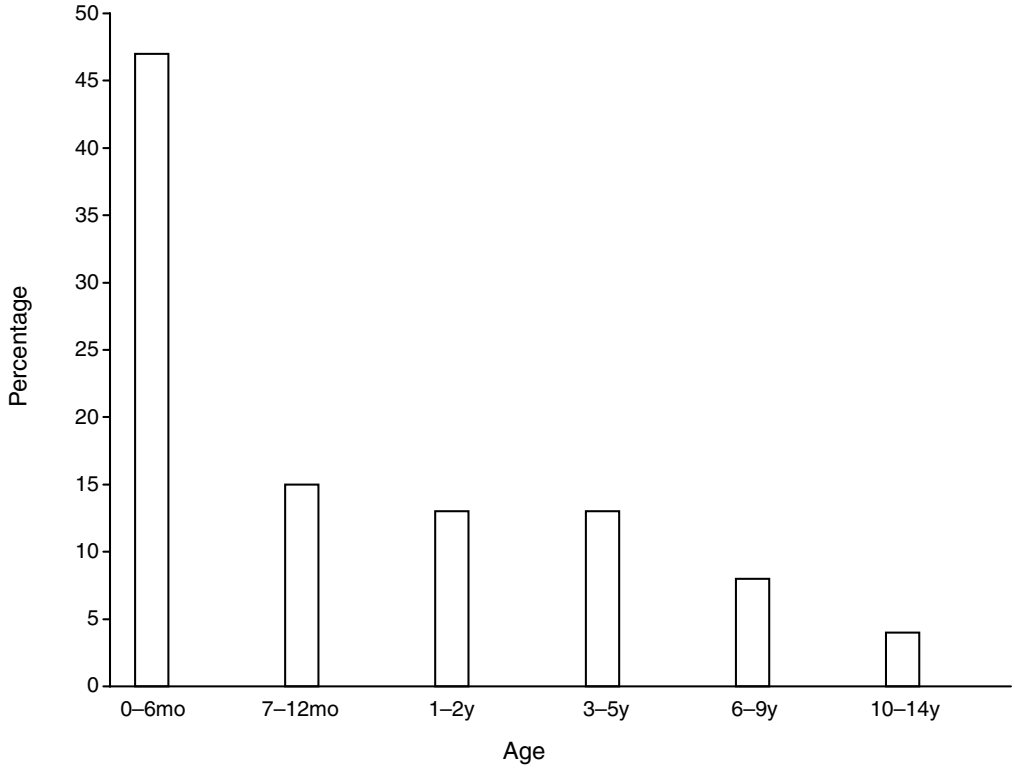

Figure 1: *Age of children in study (n=75).*

DATA ANALYSIS

The findings of the clinical evaluations were compared with findings on the VFSS and submitted to the Fisher's exact test. Some children were assessed using more than one food consistency. To avoid repeated measures, which would violate the assumption of independence of the Fisher's exact test, data were split into two categories of food consistency (fluid and semi-solids) for both penetration and aspiration. This categorization also served to stratify for age and oral motor development as young infants were only given fluids. Data were analyzed using fourfold tables to determine the sensitivity, specificity, and positive and negative predictive values of the clinical evaluations compared with VFSS. In this study, sensitivity measures the clinical examination's ability to identify true aspirators, and specificity measures the clinical examination's ability to identify true non-aspirators.

Mean values were calculated for the therapists' confidence ratings on clinical evaluation and compared with their accuracy as confirmed by VFSS.

Logistic regression was used to develop the prediction models because of the categorical nature of the dependent variables. The clinical variables examined for prediction models were: delayed swallow, cough, gag, reflux behaviours, abnormal respiration, colour changes (facial or upper lip), and voice changes. When variables were highly correlated with each other, the variable most clinically observable and least open to interpretation was entered into the prediction analysis. For example, colour changes are more readily observable than determining how to evaluate abnormal respirations.

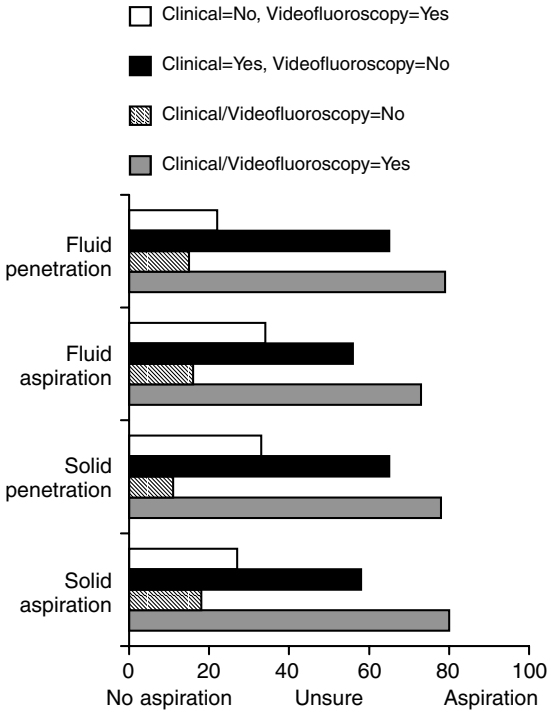

Figure 2: *Therapists' mean confidence values. 100%, certain penetration and aspiration; 0%, certain no penetration and aspiration; 50%, uncertain about penetration and aspiration.*

Results

Reliability testing of six therapists performed during a pilot study achieved an intraclass correlation coefficient of 0.91.

The age range of the children was 0 to 14 years, with 62% being younger than 12 months (Fig. 1). Out of 120 clinical feeding evaluations over a 15-month period, 75 underwent VFSS and these children are the participants in this research. Children were classified according to reason for referral as this represented the feeding issue more accurately than the diagnosis. Different diagnosis could have the same reason for referral. See Table I for reasons for referral to the Feeding and Swallowing Service and types of diagnosis included in the population of children.

ASPIRATION

The overall prevalence of aspiration was 40% for fluids and 18% for solids.

Table II presents the statistically significant association ($p=0.002$) between VFSS and clinical evaluation in detecting aspiration of fluids. The clinical assessment correctly identified 92% of the children who aspirated on fluids (sensitivity) and 46% of those children who did not aspirate on fluids (specificity). The positive predictive value or the proportion of children who were found to actually aspirate in all who are evaluated as aspirating on fluids was 54%. The negative predictive value or the proportion of children who were found to not aspirate in all who were evaluated as not aspirating was 89%.

Table III illustrates non-significant results for aspiration of solids ($p=0.67$). The sensitivity of the clinical assessment was 33%, i.e. therapists correctly identified two out of six children as aspirating solids. The specificity was 65%, i.e. therapists correctly identified 17 out of 26 non-aspirators. The positive predictive value of the clinical assessment in the detection of fluid aspiration was 18%, which tells us that therapists said 11 children were aspirating and that only two of these were accurate. The negative predictive value was 81%, illustrating that therapists correctly identified 17 out of the 21 whom they said were not aspirating.

PENETRATION

There is a significant association between VFSS and clinical evaluation in detecting penetration of fluids ($p=0.05$), as seen in Table IV. These results show a sensitivity of 80% and specificity of 42%, with positive and negative predictive values of 65% and 60% respectively of the clinical evaluation's ability to detect penetration of fluid.

As shown in Table V, the clinical assessment correctly identified 70% of the children who penetrated solids (sensitivity) and 55% of those children who did not (specificity). The positive predictive value of the clinical assessment in the detection of penetration of solids was 41% and the negative predictive value was 80%. These results did not reach statistical significance ($p=0.18$).

THERAPISTS' CONFIDENCE RATINGS

Figure 2 presents the calculated mean ratings of clinicians' confidence about their evaluations of aspiration and penetration compared with the accuracy of their ratings on VFSS. One hundred per cent illustrates certainty that penetration and/or aspiration are present; 0% represents certainty that penetration and/or aspiration are not present; and 50% suggests uncertainty in this decision.

For detection of fluid aspiration, clinicians were 73% sure when aspiration was present and certain at 16% when there was no aspiration. Similarly, the confidence rating for solid aspiration when it was present was 80%, and 18% when there was no aspiration. The pattern is similar for penetration of fluids and solids.

In the situations where the VFSS and therapists disagreed the confidence ratings reflected uncertainty. The confidence ratings ranged from 56% to 65% when the therapist said yes and the VFSS showed no aspiration or penetration. When the therapists said no to the presence of aspiration or penetration and the VFSS showed that it was in fact present, the confidence rating ranged from 22% to 34%.

CLINICAL PREDICTORS OF ASPIRATION AND PENETRATION

Several statistically significant models ($p<0.05$) emerged from

Table II: Aspiration, fluids ($p=0.002$)

Clinical Assessment	*Videofluoroscopic swallowing studies*		
	Present	*Absent*	*Total*
+	22 (a)	19 (b)	41
–	2 (c)	16 (d)	18
Total	24	35	59

Sensitivity: a/(a+c)=22/24=92%±11% (95% CI).
Specificity: d/(b+d)=16/35=46%±17% (95% CI).
Positive predictive value: a/(a+b)=22/41=54%±15% (95% CI).
Negative predictive value: d/(c+d)=16/18=89%±14% (95% CI).

Table III: Aspiration, solids ($p=0.67$)

Clinical assessment	*Videofluoroscopic swallowing studies*		
	Present	*Absent*	*Total*
+	2 (a)	9 (b)	11
–	4 (c)	17 (d)	21
Total	6	26	32

Sensitivity: a/(a+c)=2/6=33%±38% (95% CI).
Specificity: d/(b+d)=17/26=65%±18% (95% CI).
Positive predictive value: a/(a+b)=2/11=18%±23% (95% CI).
Negative predictive value: d/(c+d)=17/21=81%±17% (95% CI).

Table IV: Penetration, fluids ($p=0.05$)

Clinical assessment	*Videofluoroscopic swallowing studies*		
	Present	*Absent*	*Total*
+	31 (a)	17 (b)	48
–	8 (c)	12 (d)	20
Total	39	29	68

Sensitivity: a/(a+c)=31/39=80%±13% (95% CI).
Specificity: d/(b+d)=12/29=42%±18% (95% CI).
Positive predictive value: a/(a+b)=31/48=65%±13% (95% CI).
Negative predictive value: d/(c+d)=12/20=60%±21% (95% CI).

Table V: Penetration, solids ($p=0.18$)

Clinical assessment	*Videofluoroscopic swallowing studies*		
	Present	*Absent*	*Total*
+	7 (a)	10 (b)	17
–	3 (c)	12 (d)	15
Total	10	22	32

Sensitivity: a/(a+c)=7/10=70%±28% (95% CI).
Specificity: d/(b+d)=12/22=55%±21% (95% CI).
Positive predictive value: a/(a+b)=7/17=41%±23% (95% CI).
Negative predictive value: d/(c+d)=12/15=80%±20% (95% CI).

Table VI: Predictors of fluid aspiration and penetration ($p<0.05$)

Model for fluid aspiration	*Relative risk*	*Model for fluid penetration*	*Relative risk*
Cough + voice changes + gag	1.7	Cough + gag + reflux behaviours	2.3
Cough + voice changes + colour changes	1.6	Cough + gag	2.1
Cough + delayed swallow + gag	1.6	Cough	1.3
Cough + voice changes	1.5	Reflux behaviours + voice changes + colour changes	0.05
Cough + delayed swallow	1.5		
Note: any variable or combination without cough does not predict aspiration.		Note: cough alone does predict, but prediction is stronger with combined model.	

Table VII: Predictors of solid aspiration and penetration ($p<0.05$)

Model for solid aspiration	*Relative risk*	*Model for solid penetration*	*Relative risk*
Colour changes + abnormal respiration	3.0	Colour changes + abnormal respiration	2.6
Cough + abnormal respiration + colour changes	2.9	Colour changes + abnormal respiration + gag	2.7
Note: cough decreases strength of model.		Note: cough adds nothing to any model.	

the analysis of fluid. Table VI presents the models and their associated relative risk (RR) value for aspiration and penetration of fluids. Cough was the most significant predictor of fluid aspiration. No model is predictive without cough. However, the model is strengthened and the RR of aspiration increases with the addition of other variables. Cough, with voice changes and gag, is the best prediction model with an RR of 1.7. Cough alone did predict penetration but the model was stronger when cough was combined with the other variables.

Prediction models displayed in Table VII for solid aspiration and penetration did not reach statistical significance. It is important to note that cough decreased the strength of the models.

Discussion

The prevalence of aspiration in the present study was 40%, which is comparable to that reported in the literature (31% to 50%; Wright et al. 1996, Logemann et al. 1999) even though these studies include adults or a combination of adults and children in their populations. Children with severe neurological disability have been reported as having a higher prevalence of aspiration at 68% to 70% (Griggs et al. 1989, Mirrett et al. 1994).

Clinical evaluation (or 'bedside' evaluation as it is sometimes referred to) is reported to be a poor predictor of aspiration in the older adult population (Sorin et al. 1988, Splaingard et al. 1988, Linden 1989, Leder et al. 1998, O'Donoghue and Bagnall 1999, Smith et al. 1999). Splaingard had 10 children in the study and found that the clinical evaluation only detected 18% of the true aspirators. These findings are in contrast to the findings in this report where only children have been studied. The sensitivity was high for fluid aspiration and penetration, meaning that clinicians were able to detect this clinically. Aspiration of solids was the exception.

The accuracy in detection of aspiration of solids was low, with a very low positive predictive value. However, only six children showed aspiration and 10 showed penetration of solids on VFSS, so our interpretation should remain guarded, as positive predictive value is closely associated with prevalence. In this study there were three times as many events (aspiration and penetration) with fluids than solids, so this could be the reason for the apparent better accuracy of clinical evaluation with fluids compared with solids. However, until we have more information, therapists should be very cautious with their decisions related to aspiration and penetration of solids as these may be more difficult to determine during a clinical evaluation and may require VFSS even more than fluids. The other important factor, as pointed out by Arvedson et al. (1994), is the prevalence of silent aspiration in children. They found a 94% rate of silent aspiration, but these children had severe neurological conditions. Silent aspiration is a well-described phenomenon and presents a major obstacle to the clinical examination (Splaingard et al. 1988, Linden et al. 1993, Leder 1997). Silent aspiration could explain our poor results with solids, but this is not supported by Loughlin's (1989) findings that most children aspirate fluids. However, if we proceed to examine the predictors of solid aspiration, we see that in fact cough was not a predictor of aspiration and if the child coughed it decreased the probability of aspiration and penetration, which lends support to the idea that the children in this study may have silently aspirated solids.

Clinicians were not as good at determining the absence of aspiration or penetration. In other words, the percentage of true negatives or specificity was low. These findings coincide with the low positive predictive values and a high false-positive rate. This suggests that therapists are erring on the side of caution. In terms of child safety and health, it would be more important to accurately detect the presence of aspiration and penetration than the absence of it. As clinicians we may accept a lower specificity so that the child with aspiration is detected whereas the child who is not aspirating will incorrectly be said to be aspirating. If we had high specificity as well as sensitivity then this would help to reduce the number of unnecessary VFSSs.

Upon examination of the relationship between the accuracy of the clinicians' evaluations and their reported level of confidence in stating their decisions (Fig. 2), some noteworthy relationships have been identified. When clinicians stated high degrees of confidence that the child was or was not penetrating and/or aspirating, their conclusions were consistent with the findings on VFSS. Discrepancies between the results of clinical evaluations and VFSS typically occurred when clinicians indicated less certainty about their decisions.

Cough was found to be the best predictor of aspiration of fluids in children. When cough is present with voice changes, gag, colour changes, or delayed swallow, the risk of aspiration is increased and clinicians should be very aware that the child could be aspirating fluids. This parallels the findings in the literature on adults (Linden et al. 1993, Mari et al. 1997, Logemann et al. 1999). Detecting aspiration of solids may be more difficult. If the child demonstrates colour changes or abnormal respirations while eating solids then aspiration should be suspected.

VFSSs are a necessary part of the comprehensive evaluation of children with feeding and swallowing difficulties because clinical evaluation can only imply penetration and aspiration. However, paediatric VFSS is not a service that is readily available to many communities, and is a costly procedure at risk of being overused or used inappropriately. As clinicians, the overall goal is to get children feeding or eating as quickly and as safely as possible, with the least hardship for the child and family. It is the responsibility of the clinician to use the best evidence to make decisions with the family to select the appropriate evaluations and interventions to achieve this goal.

LIMITATIONS OF THE STUDY

There was a potential sample bias introduced into this study because all children included in it were referred to the Feeding and Swallowing Service owing to complicated feeding and swallowing issues. As this was not a study of prognosis but accuracy of a diagnostic test, this should not have unduly influenced the results. Referral filter bias and diagnostic suspicion bias were also possibilities. A referral to the clinic may have suggested that penetration or aspiration or both were being suspected before the evaluation. The large spectrum of children included a range of ages with different types of feeding difficulty, of variable severity, and it included children who aspirated and those who did not. This spectrum should have prevented influencing the test's predictive value, as would be the case if only children who were aspirating were included.

Conclusions and clinical implications

VFSS remains the best test to determine the presence of aspiration and penetration, but it may not always be needed as part of a swallowing assessment. Experienced therapists, defined in our study as having greater than 5 years' experience in paediatric feeding and swallowing, are very accurate in their detection of fluid aspiration and penetration during the clinical evaluation. They are not very accurate in the detection of aspiration of solids. Experienced therapists should use their uncertainty about the presence or absence of penetration or aspiration as an indicator that further diagnostic tests are required, specifically VFSS. They should also exercise particular caution in judgements about aspiration with solid textures.

In children, cough is the best predictor of fluid aspiration and penetration. Cough does not seem to predict solid aspiration. This information can contribute to therapists' accuracy in determining the presence of aspiration or penetration during the clinical evaluation of the child with a feeding and swallowing problem.

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Appendix I: Clinical evaluation form

CLINICAL EVALUATION OF ORAL MOTOR FUNCTION & SWALLOWING

Key: ✓ = yes
✗ = no
N/O = not observed

Name **Date**
ID **DOB** **Reason for Referral**
Diagnosis **Therapist**

	Viscosity					
	Thin Fluid 100	Thick Fluid 250	Thin Puree 800	Puree 2000	Solid	Comments
Ability to take fluid in **Spoon**						
Bottle						
Cup						
Straw						
Feeding Position: Reclined						
Upright in arms						
Upright in chair						
Control of bolus/food movement to back of oral cavity						
Delayed swallow						
Protective mechanism present: cough						
gag						
Nasal regurgitation						
Drooling/saliva control absent						
Reflux observed						
Reflux behaviors present						
Abnormal respiration						
Color changes present						
Voice changes: hoarse; wet/gurgley						
Asymmetrical function: Tongue						
Swallow						
Pooling suspected						
Aspiration suspected: Silent						
Overt						
Confidence Rating of your evaluation re aspirating. Rate as a percentage	100% confident not aspirating |----------| 0		not sure |----------| 50			100% confident aspirating |----------| 100
Confidence Rating of your evaluation re penetration. Rate as a percentage	100% confident not penetrating |----------| 0		not sure |----------| 50			100% confident penetrating |----------| 100

Appendix II: Videofluoroscopy evaluation form

VIDEOFLUOROSCOPY OF ORAL MOTOR FUNCTION & SWALLOWING

Key: ✓ = yes
✗ = no
N/O = not observed

Name **Date**
ID **DOB** **Reason for Referral**
Diagnosis **Therapist**
Video tape sequence **Radiologist**

	Viscosity					
	Thin Fluid 100	Thick Fluid 250	Thin Puree 800	Puree 2000	Solid	Comments
Ability to take fluid in Spoon Bottle Cup Straw						
Delayed transit time mouth ➡ swallow						
Inadequate lip closure/ function						
Control of bolus/food movement to back of oral cavity						
Delayed swallow						
Protective mechanism present: cough **gag**						
Nasal regurgitation						
Drooling/saliva control absent						
Reflux observed						
Reflux behaviours present						
Asymmetrical function: Tongue **Swallow**						
Vallecular pooling						
Vallecular stasis						
Falling to piriform						
Piriform stasis						
Penetration						
Aspiration						