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Bedside Diagnosis of Dysphagia: A Systematic Review

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Abstract

Background—Dysphagia is associated with aspiration, pneumonia and malnutrition, but remains challenging to identify at the bedside. A variety of exam protocols and maneuvers are commonly used, but the efficacy of these maneuvers is highly variable.

Methods—We conducted a comprehensive search of seven databases, including MEDLINE, EMBASE and Scopus, from each database's earliest inception through June 5th, 2013. Studies reporting diagnostic performance of a bedside examination maneuver compared to a reference gold standard (videofluoroscopic swallow study [VFSS] or flexible endoscopic evaluation of swallowing with sensory testing [FEEST]) were included for analysis. From each study, data were abstracted based on the type of diagnostic method and reference standard study population and inclusion/exclusion characteristics, design and prediction of aspiration.

Results—The search strategy identified 38 articles meeting inclusion criteria. Overall, most bedside examinations lacked sufficient sensitivity to be used for screening purposes across all patient populations examined. Individual studies found dysphonia assessments, abnormal pharyngeal sensation assessments, dual axis accelerometry, and one description of water swallow testing to be sensitive tools, but none were reported as consistently sensitive. A preponderance of identified studies was in post-stroke adults, limiting the generalizability of results.

Conclusions—No bedside screening protocol has been shown to provide adequate predictive value for presence of aspiration. Several individual exam maneuvers demonstrated reasonable sensitivity, but reproducibility and consistency of these protocols was not established. More research is needed to design an optimal protocol for dysphagia detection.

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Keywords

Bedside swallow; videofluoroscopy; dysphagia; aspiration; systematic review

Introduction

Dysphagia is a serious medical condition that can lead to aspiration pneumonia, malnutrition, and dehydration.¹ Dysphagia is the result of a variety of medical etiologies, including stroke, traumatic brain injury, progressive neurologic conditions, head and neck cancers, and general deconditioning. Prevalence estimates for dysphagia vary depending upon the etiology and patient age, but estimates as high as 38% for lifetime prevalence have been reported in those over age 65.²

In order to avoid adverse health outcomes, early detection of dysphagia is essential. In hospitalized patients, early detection has been associated with reduced risk of pneumonia, decreased length of hospital stay, and improved cost-effectiveness resulting from a reduction in hospital days due to fewer cases of aspiration pneumonia.³⁻⁵ Stroke guidelines in the U.S. recommend screening for dysphagia for all patients admitted with stroke.⁶ Consequently, the majority of screening procedures have been designed for and tested in this population.⁷⁻¹⁰

The videofluoroscopic swallow study (VFSS) is a commonly accepted “reference standard” instrumental evaluation technique for dysphagia as it provides the most comprehensive information regarding anatomic and physiologic function for swallowing diagnosis and treatment. Flexible endoscopic evaluation of swallowing (FEES) is also available as are several less commonly used techniques (scintigraphy, manometry, and ultrasound). Due to availability, patient compliance, and expertise needed, it is not possible to perform instrumental examination on every patient with suspected dysphagia. Therefore, a number of minimally invasive bedside screening procedures for dysphagia have been developed.

The value of any diagnostic screening test centers on performance characteristics which, under ideal circumstances, include a positive result for all those who have dysphagia (sensitivity) and negative result for all those who do not have dysphagia (specificity). Such an ideal screening procedure would reduce unnecessary referrals and testing, thus resulting in cost savings, more effective utilization of speech-language pathology consultation services, and less unnecessary radiation exposure. In addition, an effective screen would detect all those at risk for aspiration pneumonia in need of intervention. However, most available bedside screening tools are lacking in some or all of these desirable attributes.^{11, 12} We undertook a systematic review and meta-analysis of bedside procedures to screen for dysphagia.

METHODS

Data Sources and Searches

We conducted a comprehensive search of seven databases, including MEDLINE, EMBASE and Scopus, from each database's earliest inception through June 9th, 2014 for English-language articles and abstracts. The search strategy was designed and conducted by an

experienced librarian with input from one researcher (JO). Controlled vocabulary supplemented with keywords was used to search for comparative studies of bedside screening tests for predicting dysphagia. The full strategy can be found in Appendix 1.

All abstracts were screened, and potentially relevant articles were identified for full text review. Those references were manually inspected to identify all relevant studies.

Study Selection

A study was eligible for inclusion if it tested a diagnostic swallow study of any variety against an acceptable reference standard (videofluoroscopic swallow study [VFSS] or flexible endoscopic evaluation of swallowing with sensory testing [FEEST]).

Data Extraction and Quality Assessment

The primary outcome of the study was aspiration, as predicted by a bedside exam compared to gold standard visualization of aspirated material entering below the vocal cords. From each study, data were abstracted based on the type of diagnostic method and reference standard study population and inclusion/exclusion characteristics, design and prediction of aspiration. Prediction of aspiration was compared against the reference standard to yield “true positives” (TP), “true negatives” (TN), “false positives” (FP) and “false negatives” (FN). Additional potential confounding variables were abstracted using a standard form based on the preferred reporting items for systematic reviews and meta-analysis (PRISMA);¹³ the full abstraction template can be found in Appendix 2.

Data Synthesis and Analysis

Sensitivity and specificity for each test that identified the presence of dysphagia was calculated for each study. These were used to generate positive and negative likelihood ratios (LRs), which were plotted on a likelihood matrix, a graphic depiction of the logarithm of the ⁺LR on the ordinate versus the logarithm of the ⁻LR on the abscissa, dividing the graphic into quadrants such that the right upper quadrant is tests that can be used for confirmation, right lower quadrant neither confirmation nor exclusion, left lower quadrant exclusion only, and left upper quadrant an ideal test with both exclusionary and confirmatory properties.¹⁴ A good screening test would thus be on the left half of the graphic as one that can effectively “rule out” dysphagia, and the ideal test with both good sensitivity and specificity would be found in the left upper quadrant. Graphics were constructed using the Stata MIDAS package.¹⁵

RESULTS

We identified 891 distinct articles. Of these, 749 were excluded based on abstract review. After reviewing the remaining 142 full text articles, 48 articles were determined to meet inclusion criteria, which included 10,437 observations across 7,414 patients (Figure 1). We initially intended to conduct meta-analysis on each type, but heterogeneity in design and statistical heterogeneity in aggregate measures precluded pooling of results.

Characteristics of Included Studies

Of the 48 included studies, the majority (n=42) were prospective observational studies,^{7, 14, 16–54} while two were randomized trials,^{55, 56} two studies were double blind observational,^{9, 16} one was a case-control design,⁵⁷ and one was a retrospective case series.⁵⁸ The majority of studies were exclusively inpatient^{7, 14, 17–19, 21, 22, 24–26, 31–33, 35, 36, 38, 39, 41, 43–47, 49, 51–53, 56, 57, 59} with five in mixed in and outpatient populations,^{20, 27, 40, 55, 60} two in outpatient populations,^{23, 42} and the remainder not reporting the setting from which they drew their study populations.

The indications for swallow evaluations fit broadly into four categories; stroke,^{7, 14, 21, 22, 24–26, 31, 33–35, 38, 39, 41–44, 46, 49, 53, 56, 58, 59} other neurologic disorders,^{17, 18, 23, 28, 40, 48} all causes,^{16, 20, 27, 29, 30, 36, 37, 45, 47, 50, 52–55, 60} and post-surgical.^{19, 32, 34} Most used VFSS as a reference standard,^{7, 14, 16–19, 21–23, 25–30, 34, 36–48, 51–56, 58–60} with eight using FEEST,^{20, 24, 31–33, 35, 50, 57} and one accepting either VSE or FEEST.⁴⁹

Studies were placed into one or more of the following four categories; subjective bedside examination,^{18, 19, 31, 34, 39, 49, 56} questionnaire-based tools,^{17, 23, 47, 54} protocolized multi-item evaluations,^{20–22, 25, 30, 33, 34, 37, 40, 45, 46, 53, 54, 59, 60} and single-item exam maneuvers, symptoms or signs.^{7, 14, 16, 24, 26–32, 34–38, 40–44, 48–52, 56, 58, 60, 61} The characteristics of all studies are detailed in Table 1.

Subjective Clinical Exam

Seven studies reported the sensitivity and specificity of subjective assessments of nurses and speech-language pathologists in observing swallowing and predicting aspiration.^{18, 19, 31, 34, 39, 49, 56} The overall distribution of studies is summarized in the likelihood matrix in Figure 2. Two studies, Chong *et al.*³¹ and Shem *et al.*,¹⁸ were on the left side of the matrix, indicating a sensitive “rule out” test. However, both were small studies, and only Chong *et al* reported reasonable sensitivity with incorporation bias from knowledge of a desaturation study outcome. Overall, subjective exams did not appear reliable in ruling out dysphagia.

Questionnaire Based Tools

Only four studies used questionnaire based tools filled out by the patient, asking about subjective assessment of dysphagia symptoms and frequency.^{17, 23, 47, 54} Yamamoto *et al.* reported results of using the swallow dysphagia questionnaire in patients with Parkinson's disease.¹⁷ Rofes *et al.* looked at the EAT-10 questionnaire among all referred patients and a small population of healthy volunteers.⁵⁴ Each was administered the questionnaire before undergoing a VF study. Overall, sensitivity and specificity were 77.8% and 84.6% respectively. Cox *et al.* studied a different questionnaire in a group of patients with inclusion body myositis, finding 70% sensitivity and 44% specificity.²³ Cohen *et al.*, 2011 examined the swallow dysphagia questionnaire across several different causes of dysphagia, finding at optimum, this test is 78% specific and 73% sensitive.⁴⁷ Rofes *et al.* had an 86% sensitivity and 68% specificity for the EAT-10 tool.⁵⁴

Multi-Item Exam Protocols

Sixteen studies reported multi-step protocols for determining a patient's risk for aspiration.^{20–22, 25, 30, 33, 34, 37, 40, 45, 46, 53, 54, 56, 59, 60} Each involved a combination of physical exam maneuvers and history elements, detailed in Table 1. This is shown in the likelihood matrix in Figure 3. Only two of these studies were in the left lower quadrant, Edmiaston *et al.* 2011²¹ and 2014.⁵³ Both studies were restricted to stroke populations, but found reasonable sensitivity and specificity in identifying dysphagia.

Individual Exam Maneuvers

Thirty studies reported the diagnostic performance of individual exam maneuvers and signs.^{7, 14, 16, 24, 26–32, 34–38, 40–44, 48–52, 55, 56, 58, 60} Each is depicted in Figure 4 as a likelihood matrix demonstrating the ⁺LR and ⁻LR for individual maneuvers as seen in the figure, most fall into the right lower quadrant, where they are not diagnostically useful tests. Studies in the left lower quadrant demonstrating the ability to exclude aspiration desirable in a screening test were dysphonia in McCullough *et al.*, 2001,³⁴ dual-axis accelerometry in Steele *et al.*, 2013,¹⁶ and the water swallow test in DePippo *et al.*, 1992,⁴⁴ and Suiter and Leder, 2008.⁵⁰

McCullough *et al.* found dysphonia to be the most discriminatory sign or symptom assessed, with an AUC of 0.818. Dysphonia was judged by a sustained “a,” and had 100% sensitivity, but only 27% specificity. “Wet voice” within the same study was slightly less informative, with AUC of 0.77 (sensitivity 50% and specificity 84%).³⁴

Kidd *et al.* verified the diagnosis of stroke, and then assessed several neurologic parameters, including speech, muscle strength and sensation. Pharyngeal sensation was assessed by touching each side of the pharyngeal wall and asking patients if they felt sensation differed from each side. Patient report of abnormal sensation during this maneuver was 80% sensitive and 86% specific as a predictor of aspiration on VFSS.⁴³

Steele *et al.* described the technique of dual axis accelerometry, where an accelerometer was placed at the midline of the neck over the cricoid cartilage during VFSS. The movement of the cricoid cartilage was captured for analysis in a computer algorithm to identify abnormal pharyngeal swallow behavior. Sensitivity was 100%, and specificity was 54%. Although the study was small (n=40), this novel method demonstrated good discrimination.⁶⁰

DePippo *et al.* evaluated a 3 oz water swallow in stroke patients. This protocol called for patients to drink the bolus of water without interruption, and be observed for 1 minute after for cough or wet-hoarse voice. Presence of either sign was considered abnormal. Overall, sensitivity was 94% and specificity 30% looking for the presence of either sign.⁴⁴ Suiter *et al.*, 2008 used a similar protocol with sensitivity of 97% and specificity of 49%.⁵⁰

Discussion

Our results show that most bedside swallow examinations lack the sensitivity to be used as a screening test for dysphagia across all patient populations examined. This is unfortunate as the ability to determine which patients require formal SLP consultation or imaging as part of

their diagnostic evaluation early in the hospital stay would lead to improved allocation of resources, cost reductions, and earlier implementation of effective therapy approaches. Furthermore, although radiation doses received during VFSS are not high when compared with other radiologic exams like CT scans,⁶² increasing awareness about the long-term malignancy risks associated with medical imaging makes it desirable to reduce any test involving ionizing radiation.

There were several categories of screening procedures identified during this review process. Those classified as subjective bedside exams and protocolized multi-item evaluations were found to have high heterogeneity in their sensitivity and specificity, though a few exam protocols did have a reasonable sensitivity and specificity.^{21, 31, 53} The following individual exam maneuvers were found to demonstrate high sensitivity and an ability to exclude aspiration: a test for dysphonia through production of a sustained “a³⁴” and use of dual-axis accelerometry¹⁶. Two other tests, the 3-oz water swallow test⁴⁴ and testing of abnormal pharyngeal sensation⁴³, were each found effective in a single study, with conflicting results from other studies.

Our results extend the findings from previous systematic reviews on this subject, most of which focused only on stroke patients.^{5, 12, 63, 64} Martino and colleagues⁵ in 2000 conducted a review focused on screening for adults post-stroke. From thirteen identified articles, it was concluded that evidence to support inclusion or exclusion of screening was poor. Daniels *et al.* 2012 conducted a systematic review of swallowing screening tools specific to patients with acute or chronic stroke.¹² Based on sixteen articles, the authors concluded that a combination of swallowing and non-swallowing features may be necessary for development of a valid screening tool. The generalizability of these reviews is limited given that all were conducted in patients post-stroke and, therefore, results and recommendations may not be generalizable to other patients.

Wilkinson *et al.*⁶⁴ conducted a recent systematic review that focused on screening techniques for inpatients 65 years or older which excluded patients with stroke or Parkinson's disease. The purpose of this review was to examine sensitivity and specificity of bedside screening tests as well as ability to accurately predict pneumonia. The authors concluded that existing evidence is not sufficient to recommend the use of bedside tests in a general older population.⁶⁴

Specific screening tools identified by Martino and colleagues⁵ to have good predictive value in detecting aspiration as a diagnostic marker of dysphagia were an abnormal test of pharyngeal sensation⁴³ and the 50-ml water swallow test. Daniels *et al.* identified a water swallow test as an important component of a screen.⁷ These results were consistent with those of this review in that the abnormal test of pharyngeal sensation⁴³ was identified for high levels of sensitivity. However, the 3-oz water swallow test,^{44, 50} rather than the 50-ml water swallow test⁴³ was identified in this review as the version of the water swallow test with the best predictive value in ruling out aspiration. Results of our review identified two additional individual items, dual axis accelerometry¹⁶ and dysphonia,³⁴ that may be important to include in a comprehensive screening tool. In the absence of better tools, the 3

oz swallow test, properly executed, seems to be the best currently available tool validated in more than one study.

Several studies in this review included an assessment of oral tongue movement that is not described thoroughly and varies between studies. Tongue movement as an individual item on a screening protocol was not found to yield high sensitivity or specificity. However, tongue movement or range of motion is only one aspect of oral tongue function; pressures produced by the tongue reflecting strength also may be important and warrant evaluation. Multiple studies have shown patients with dysphagia resulting from a variety of etiologies to produce lower than normal maximum isometric lingual pressures,^{65–70} or pressures produced when the tongue is pushed as hard as possible against the hard palate. Tongue strengthening protocols that results in higher maximum isometric lingual pressures have been shown to carry over to positive changes in swallow function.^{71–75} Inclusion of tongue pressure measurement in a comprehensive screening tool may help to improve predictive capabilities.

We believe our results have implications for practicing clinicians, and serve as a call to action for development of an easy to perform, accurate tool for dysphagia screening. Future prospective studies should focus on practical tools that can be deployed at the bedside, and correlate the results with not only “gold standard” VFSS and FEES, but with clinical outcomes, such as pneumonia and aspiration events leading to prolonged length of stay.

There were several limitations to this review. High levels of heterogeneity were reported in the screening tests present in the literature, precluding meaningful meta-analysis. In addition, the majority of studies included were in post-stroke adults, which limits the generalizability of results.

In conclusion, no screening protocol has been shown to provide adequate predictive value for presence of aspiration. Several individual exam maneuvers demonstrate high sensitivity; however, the most effective combination of screening protocol components is unknown. There is a need for future research focused on the development of a comprehensive screening tool that can be applied across patient populations for accurate detection of dysphagia as well as prediction of other adverse health outcomes, including pneumonia.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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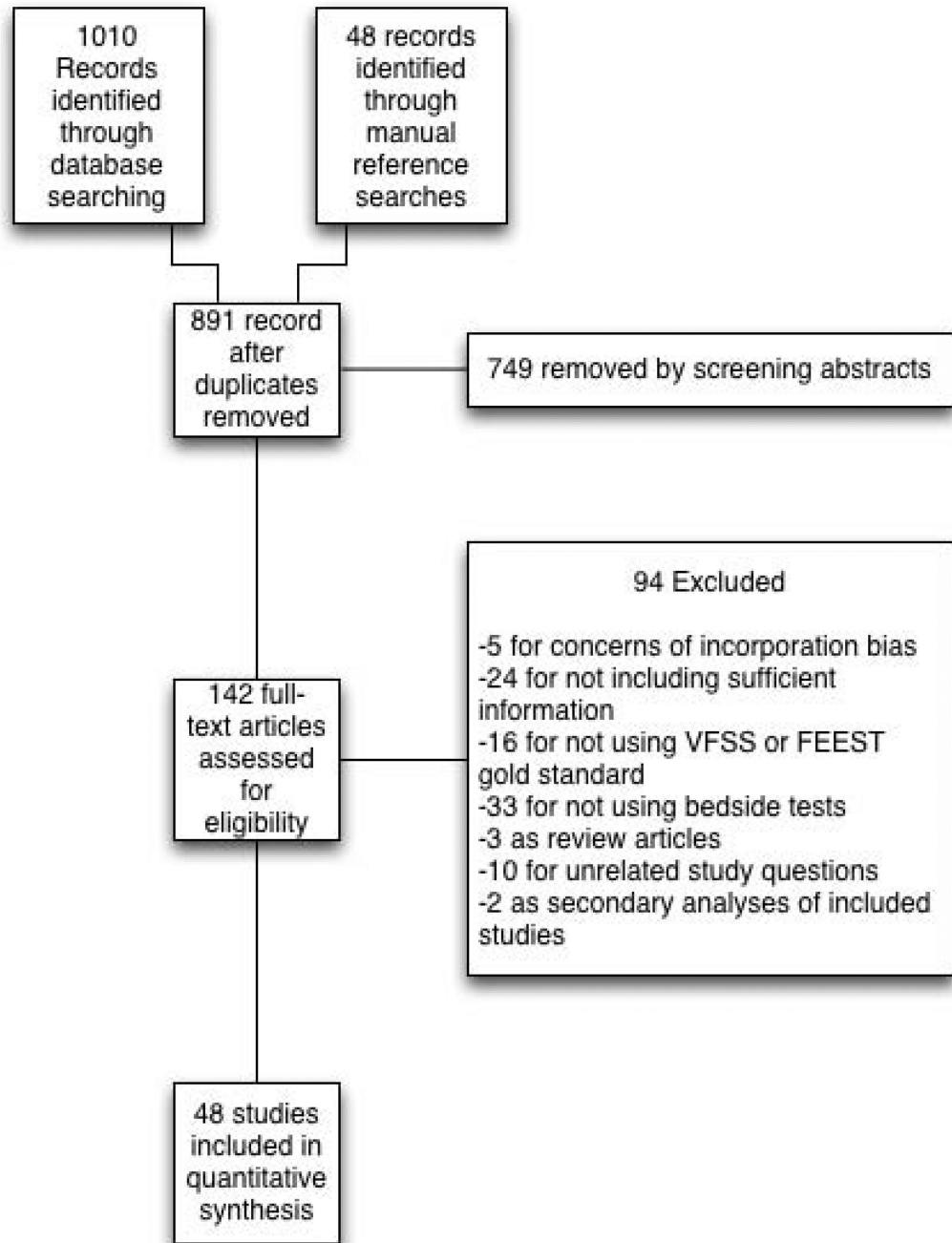


Figure 1. PRISMA flow diagram

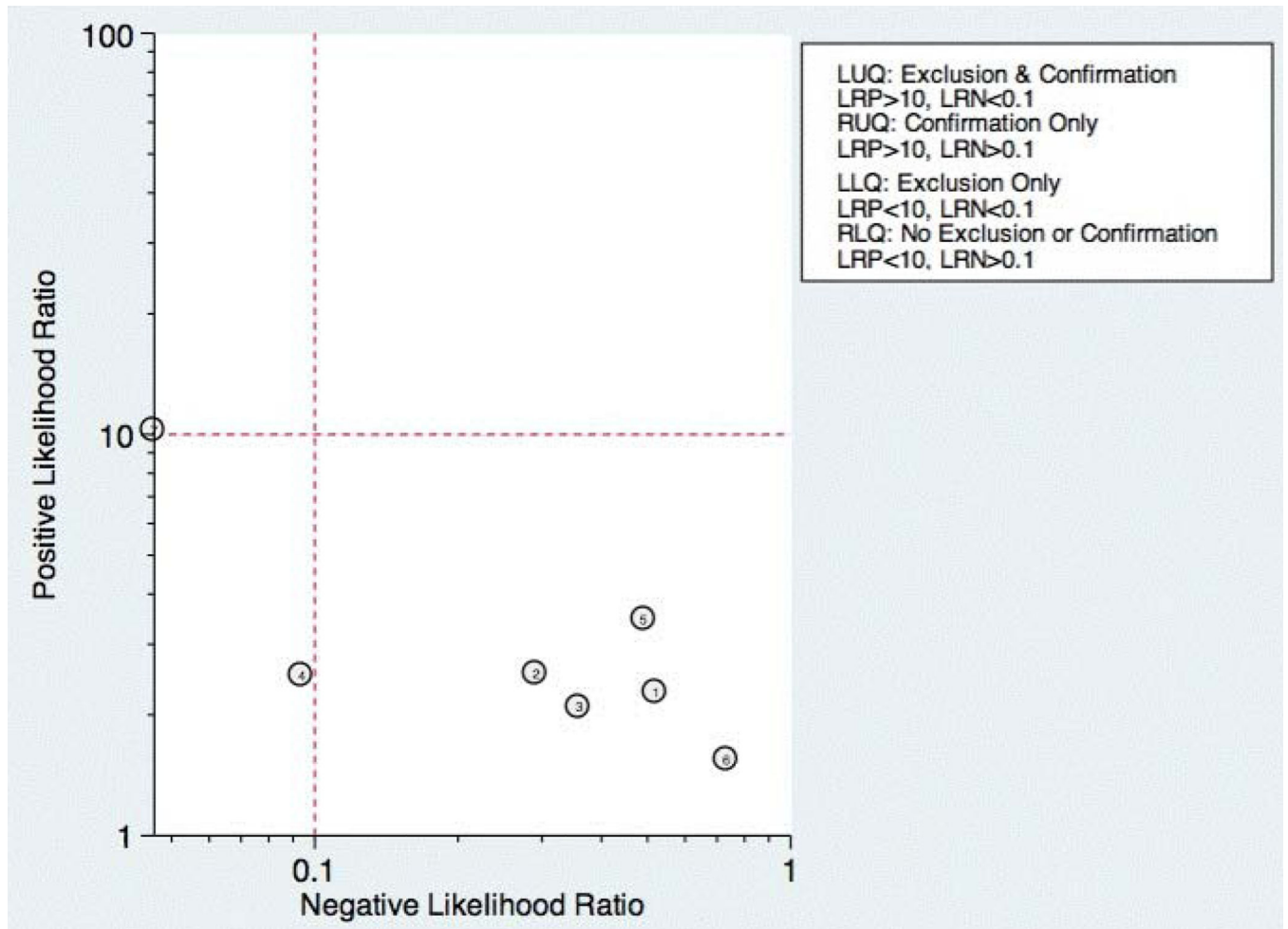


Figure 2. Likelihood Matrix for curve for subjective clinical exam

Each point corresponds to a study as follows: 1=Smithard *et al.*, 1998; 2=Smith *et al.*, 2000; 3=McCullough *et al.*, 2001; 4=Chong *et al.*, 2003; 5= Smith-Hammond *et al.*, 2009, 6=Bhama *et al.*, 2012, 7= Shem *et al.*, 2012

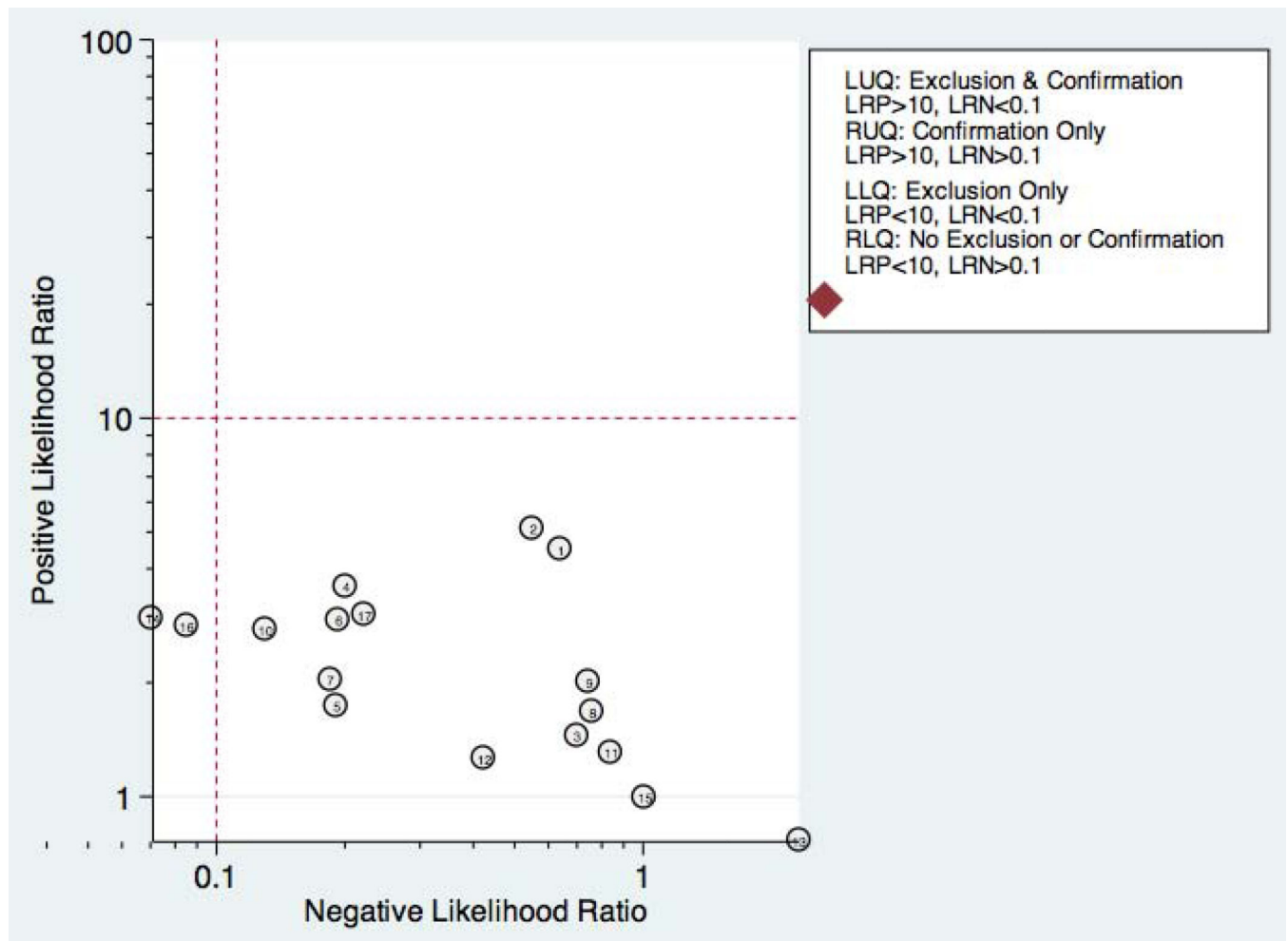


Figure 3. Likelihood Matrix of Multi-Item Protocols

1=Splaingard *et al.*, 1988; 2= Mari *et al.*, 1997, 3=Logemann *et al.*, 1999; 4=Smith *et al.*, 2000; 5= McCullough *et al.*, 2001, 6=Leder *et al.*, 2002; 7=Tohara *et al.*, 2003; 8=Ramsey *et al.*, 2006; 9=Baylow *et al.*, 2009, 10=Martino *et al.*, 2009; 11=Leigh *et al.*, 2010, 12=Mandysova *et al.*, 2011, 13=Steele *et al.*, 2011 (SLP assessment); 14=Edmiaston *et al.*, 2011; 15=Steele et al (RN assessment), 16=Edmiaston *et al.*, 2014 17=Rofes *et al.*, 2014

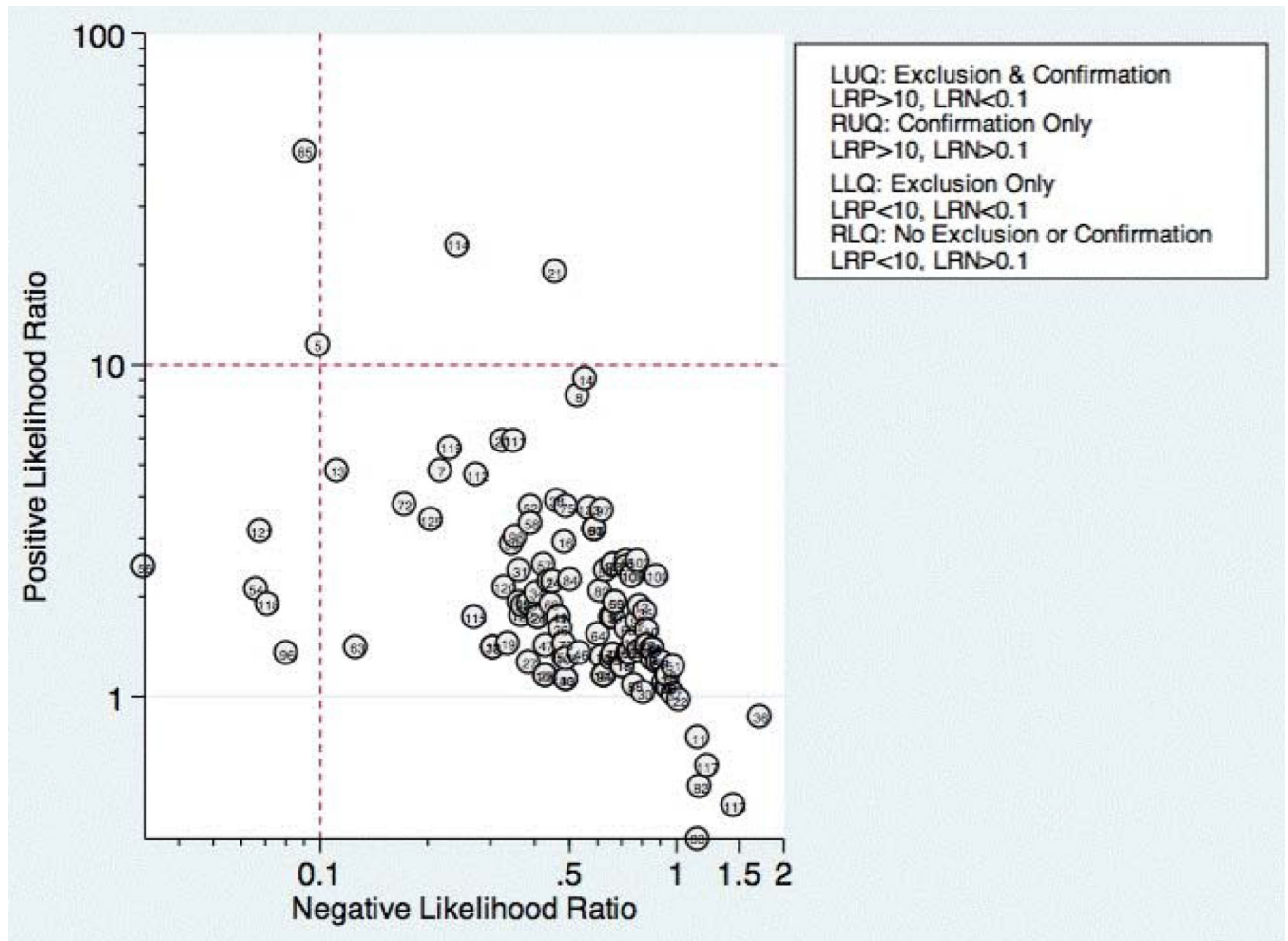


Figure 4. Likelihood matrix of individual exam maneuvers

Studies in the LLQ demonstrating the ability to exclude aspiration were 56= Kidd *et al.*, 1993 (abnormal pharyngeal sensation) 96=McCulloch *et al.*, 2001 (dysphonia), 54=Steele *et al.*, 2013 (dual axis accelerometry), 121=DePippo *et al.*, 1992 (water swallow test) and 118=Suiter and Leder *et al.*, 2008 (water swallow test). Key to other tests can be located in the appendix

Table 1

Characteristics of included studies.

Study	Location	Design	Mean Age (SD)	Reason(s) for dysphagia	Index Test	Description	Reference Standard	Sample size (No of patients)	Sample Size (No of observations)
Splaingard <i>et al.</i> , 1988 ⁴⁵	Milwaukee, Wisconsin, USA	Prospective Observational Study	NR	Multiple	Clinical Bedside Swallow Exam	Combination of scored comprehensive physical exam, history and observed swallow	VFSS	107	107
DePippo <i>et al.</i> , 1992 ⁴⁴	White Plains, NY, USA	Prospective Observational Study	71 (10)	Stroke	WST	Observation of swallow	VFSS	44	44
Homer <i>et al.</i> , 1992 ⁵⁷	Durham, North Carolina, USA	Retrospective Case Series	64**	Stroke	Clinical bedside swallow evaluation	VFSS	38	114	114
Kidd <i>et al.</i> , 1993 ⁴³	Belfast, UK	Prospective Observational Study	72 (10)	Stroke	Bedside 50 mL swallow evaluation	Patient swallows 50 mL of water in 5 mL aliquots, with therapist assessing for choking, coughing or change in vocal quality after each swallow	VFSS	60	240
Collins <i>et al.</i> , 1997 ⁴²	Southampton, UK	Prospective Observational Study	65**	Stroke	Desaturation	Desaturation of at least 2% during videofluoroscopic study	VFSS	54	54
Daniels <i>et al.</i> , 1997 ⁴¹	New Orleans, Louisiana, USA	Prospective Observational Study	66 (11)	Stroke	Clinical Bedside examination	6 individual bedside assessments (dysphonia, dysphagia, cough before/after swallow, gag reflex and voice change) examined as predictors for aspiration risk	VFSS	59	354
Mari <i>et al.</i> , 1997 ⁴⁰	Ancona, Italy	Prospective Observational Study	60 (16)	Mixed neurologic diseases	Combined history and exam	Assessed symptoms of dysphagia, cough, and 3-oz water swallow	VFSS	93	372
Daniels <i>et al.</i> , 1998 ⁷	New Orleans, Louisiana, USA	Prospective Observational Study	66 (11)	Stroke	Clinical bedside swallow evaluation	Describes sensitivity and specificity of several component physical exam	VFSS	55	330

Study	Location	Design	Mean Age (SD)	Reason(s) for dysphagia	Index Test	Description	Reference Standard	Sample size (No of patients)	Sample Size (No of observations)
Smithard <i>et al.</i> , 1998 ³⁹	Ashford, UK	Prospective Observational Study	79**	Stroke	Clinical bedside swallow evaluation	maneuvers comprising the bedside exam	VFSS	83	249
Addington <i>et al.</i> , 1999 ³⁸	Kansas City, Missouri, USA	Prospective Observational Study	80**	Stroke	NR	Reflex Cough	VFSS	40	40
Logemann <i>et al.</i> , 1999 ³⁷	Evanston, Illinois, USA	Prospective Observational Study	65*	Multiple	Northwestern Dysphagia Check Sheet	28-item screening procedure including history, observed swallows and physical exam	VFSS	200	1400
Smith <i>et al.</i> , 2000 ⁵⁵	Manchester, UK	Double blind observational	69*	Stroke	Clinical bedside swallow evaluation, pulse oximetry evaluation	After eating/drinking, patient is evaluated for signs of aspiration including coughing, choking or "wet voice." Procedure is repeated with several consistencies. Also evaluated if patient desaturates by at least 2% during evaluation.	VFSS	53	53
Warms <i>et al.</i> , 2000 ³⁶	Melbourne, Australia	Prospective Observational Study	67*	Multiple	Wet voice	Voice was recorded and analyzed with Sony DAT during videofluoroscopy	VFSS	23	708
Lim <i>et al.</i> , 2001 ³⁵	Singapore, Singapore	Prospective Observational Study	NR	Stroke	Water Swallow Test, desaturation during swallow	50 mL swallow done in 5 mL aliquots with assessment of phonation/choking afterwards, desaturation >2% during swallow	FEEST	50	100
McCullough <i>et al.</i> , 2001 ³⁴	Nashville, Tennessee, USA	Prospective Observational Study	60 (10)	Stroke	Clinical bedside swallow evaluation	15-item physical exam with observed swallow	VFSS	2040	60
Rosen <i>et al.</i> , 2001 ³⁴	Newark, New Jersey, USA	Prospective Observational Study	60*	Head and Neck cancer	Wet voice	Observation of swallow	VFSS	26	26

Study	Location	Design	Mean Age (SD)	Reason(s) for dysphagia	Index Test	Description	Reference Standard	Sample size (No of patients)	Sample Size (No of observations)
Leder <i>et al.</i> , 2002 ³³	New Haven, Connecticut, USA	Prospective Observational Study	70**	Stroke	Clinical exam	Checklist evaluation of cough and voice change after swallow, volitional cough, dysphonia, dysarthria, and abnormal gag	FEEST	49	49
Belafsky <i>et al.</i> , 2003 ³²	San Francisco, California, USA	Prospective Observational Study	65 (11)	Post-Tracheostomy patients	Modified Evans Blue Dye Test (MEBDT)	Three boluses of dye-impregnated ice are given to patient. Tracheal secretions are suctioned, and evaluated for the presence of dye.	FEES	30	30
Chong <i>et al.</i> , 2003 ³¹	Jalan Tan Tock Seng, Singapore	Prospective Observational Study	75 (7)	Stroke	Water Swallow Test, desaturation during, Clinical exam	Subjective exam, drinking 50 mL of water in 10 mL aliquots, and evaluating for desaturation >2% during FEES	FEEST	50	150
Tohara <i>et al.</i> , 2003 ³⁰	Tokyo, Japan	Prospective Observational Study	63 (17)	Multiple	Food/water swallow tests, and a combination of the two	Protocolized observation of sequential food and water swallows with scored outcomes	VFSS	63	63
Rosenbek <i>et al.</i> , 2004 ¹⁴	Gainesville, Florida, USA	Prospective Observational Study	68**	Stroke	Clinical bedside swallow evaluation	Describes 5 parameters of voice quality and 15 physical examination maneuvers used	VFSS	60	1200
Ryu <i>et al.</i> , 2004 ²⁹	Seoul, South Korea	Prospective Observational Study	64 (14)	Multiple	Voice analysis parameters	Analysis of the "a" vowel sound with Visi-Pitch II 3300	VFSS	93	372
Shaw <i>et al.</i> , 2004 ²⁸	Sheffield, UK	Prospective Observational Study	71*	Neurologic disease	Bronchial auscultation	Auscultation over the right main bronchus during trial feeding to listen for sounds of aspiration	VFSS	105	105
Wu <i>et al.</i> , 2004 ²⁷	Taipei, Taiwan	Prospective Observational Study	72 (11)	Multiple	100- ml swallow test	Patient lifts a glass of 100 mL of water and drinks as quickly as possible, and is assessed for signs of choking, coughing or wet voice, and is timed for speed of	VFSS	54	54

Study	Location	Design	Mean Age (SD)	Reason(s) for dysphagia	Index Test	Description	Reference Standard	Sample size (No of patients)	Sample Size (No of observations)
Nishiwaki <i>et al.</i> , 2005 ²⁶	Shizuoka, Japan	Prospective Observational Study	70**	Stroke	Clinical bedside swallow evaluation	Describes sensitivity and specificity of several component physical exam maneuvers comprising the bedside exam	VFSS	31	248
Wang <i>et al.</i> , 2005 ³⁴	Taipei, Taiwan	Prospective double-blind study	41**	Multiple	Desaturation	Desaturation of at least 2% during videofluoroscopic study	VFSS	60	60
Ramsey <i>et al.</i> , 2006 ²⁵	Kent, UK	Prospective Observational Study	71 (10)	Stroke	BSA	Assessment of lip seal, tongue movement, voice quality, cough, and observed 5 mL swallow	VFSS	54	54
Trapl <i>et al.</i> , 2007 ²⁴	Krems, Austria	Prospective Observational Study	76 (2)	Stroke	Gugging Swallow Screen	Progressive observed swallow trials with saliva, then w mL liquid, then dry bread	FEEST	49	49
Suiter and Leder, 2008 ⁸⁰	Several centers across the USA	Prospective Observational Study	68.3	Multiple	3 oz water swallow test	Observation of swallow	FEEST	3000	3000
Wagasugi <i>et al.</i> , 2008 ⁵¹	Tokyo, Japan	Prospective Observational Study	NR	Multiple	Cough test	Acoustic analysis of cough	VFSS	204	204
Baylow <i>et al.</i> , 2009 ⁴⁶	New York, New York, USA	Prospective Observational Study	NR	Stroke	Northwestern Dysphagia Check Sheet	28 item screening procedure including history, observed swallows and physical exam	VFSS	15	30
Cox <i>et al.</i> , 2009 ²³	Leiden, The Netherlands	Prospective Observational Study	68 (8)	Inclusion body myositis	Dysphagia questionnaire	Questionnaire assessing symptoms of dysphagia	VFSS	57	57
Kagaya <i>et al.</i> , 2010 ²²	Tokyo, Japan	Prospective Observational Study	NR	Multiple	Simple Swallow Provocation Test	Injection of 1–2 mL water through nasal tube directed at the suprapharynx	VFSS	46	46
Martino <i>et al.</i> , 2009 ⁵⁸	Toronto, Canada	Randomized trial	69 (14)	Stroke	Toronto Bedside Swallow Screening	4 item physical assessment	VFSS	59	59

Study	Location	Design	Mean Age (SD)	Reason(s) for dysphagia	Index Test	Description	Reference Standard	Sample size (No of patients)	Sample Size (No of observations)
Santamato et al., 2009 ⁵⁶	Bari, Italy	Case Control	NR	Multiple	Acoustic analysis-post swallow apnea Test (TOR-BSST)	including Kidd water swallow test, pharyngeal sensation, tongue movement and dysphonia (before and after water swallow)	VFSS	15	15
Smith Hammond et al., 2009 ⁴⁹	Durham, North Carolina, USA	Prospective observational study	67.7 (1.2)	Multiple	Cough expiratory phase peak flow	Acoustic analysis of cough	VFSS or FEES	96	288
Leigh et al., 2010 ²²	Seoul, South Korea	Prospective Observational Study	NR	Stroke	Clinical bedside swallow evaluation	Not described	VFSS	167	167
Pitts et al., 2010 ⁴⁸	Gainesville, Florida, USA	Prospective Observational Study	NR	Parkinson	Cough compression phase duration	Acoustic analysis of cough	VFSS	58	232
Cohen et al., 2011 ⁴⁷	Tel Aviv, Israel	Prospective observational Study	NR	Multiple	Swallow Disturbance Questionnaire	15 item questionnaire	FEES	100	100
Edmiaston et al., 2011 ²¹	St. Louis, Missouri, USA	Prospective Observational Study	63 ^{**}	Stroke	SWALLOW-3D Acute Stroke Dysphagia Screen	5 item screen including mental status, asymmetry or weakness of face, tongue or palate, and subjective signs of aspiration when drinking 3oz water	VFSS	225	225
Mandysova et al., 2011 ²⁰	Pardubice, Czech Republic	Prospective Observational Study	69 (13)	Multiple	Brief Bedside Dysphagia Screening Test (BBDS Test)	8- item physician exam including ability to clench teeth, symmetry/strength of tongue, facial and shoulder muscles, dysarthria, and choking, coughing or dripping of food after taking thick liquid	FEES	87	87
Steele et al., 2011 ⁵⁹	Toronto, Canada	Double blind observational	67 [*]	Stroke	4-item bedside exam	Tongue lateralization, cough, throat clear and voice quality	VFSS	400	40

Study	Location	Design	Mean Age (SD)	Reason(s) for dysphagia	Index Test	Description	Reference Standard	Sample size (No of patients)	Sample Size (No of observations)
Yamamoto <i>et al.</i> , 2011 ¹⁷	Kodaira, Japan	Prospective Observational Study	67 (9)	Parkinson's Disease	Swallowing Disturbance Questionnaire	15 item questionnaire	VFSS	61	61
Bhama <i>et al.</i> , 2012 ¹⁹	Pittsburgh, Pennsylvania, USA	Prospective Observational Study	57 (14)	Post-lung transplant	Clinical bedside swallow evaluation	Not described	VFSS	128	128
Shem <i>et al.</i> , 2012 ¹⁸	San Jose, California, USA	Prospective Observational Study	42 (17)	Spinal cord injuries resulting in tetraplegia	Clinical bedside swallow evaluation	After eating/drinking, patient is evaluated for signs of aspiration including coughing, choking or "wet voice." Procedure is repeated with several consistencies.	VFSS	26	26
Steele <i>et al.</i> , 2013 ¹⁶	Toronto, Canada	Prospective Observational Study	67 (14)	Multiple	Dual-axis Accelerometry	Computed accelerometry of swallow	VFSS	37	37
Edmiaston <i>et al.</i> , 2014 ⁵³	St. Louis, Missouri, USA	Prospective Observational Study	63 (15)	Stroke	Barnes Jewish Stroke Dysphagia Screen	5 item screen including mental status, asymmetry or weakness of face, tongue or palate, and subjective signs of aspiration when drinking 3 oz water	VFSS	225	225
Rofes <i>et al.</i> , 2014 ⁵⁴	Barcelona, Spain	Prospective Observational Study	74 (12)	Mixed	EAT-10 questionnaire and variable viscosity swallow test	Symptom based questionnaire (EAT-10) and repeated observations and measurements of swallow with different thickness liquids	VFS	134	134

NR=Not reported.

* =median provided instead of mean.

** =SD not available.