Received: 16 June 2021 | Accepted: 22 June 2021

DOI: 10.1002/lio2.615

ORIGINAL RESEARCH

Laryngoscope Investigative Otolaryngology

Predictive values of static endoscopic evaluation of swallowing in adults

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Abstract

Objective: Static endoscopic evaluation of swallowing (SEES) is an instrumental evaluation developed for in-office identification of patients who may benefit from a modified barium swallow study (MBSS). We aim to determine the predictive value of SEES for evaluating dysphagia.

Methods: A retrospective case series was performed on adults evaluated for dysphagia using SEES followed by MBSS at a single tertiary care center. Studies were evaluated by two blinded expert raters.

Results: Fifty-eight patients were included. Thin liquid penetration on SEES had a sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of 0.86 (95% CI 0.70-0.95), 0.63 (95% CI 0.24-0.91), 0.91 (95% CI 0.76-0.98), and 0.5 (0.19-0.81), respectively, for predicting thin liquid penetration on MBSS, and 1.0 (95% CI 0.59-1.0), 0.29 (95% CI 0.15-0.47), 0.23 (95% CI 0.10-0.41), and 1.0 (95% CI 0.69-1.0) for predicting thin liquid aspiration on MBSS. Thin liquid aspiration on SEES had a sensitivity, specificity, PPV, and NPV of 0.67 (95% CI 0.09-0.99), 0.85 (95% CI 0.66-0.96), 0.33 (95% CI 0.04-0.78), and 0.96 (95% CI 0.79-1.0), respectively, for predicting thin liquid aspiration on MBSS.

Conclusions: SEES may be used as an objective in-office test to screen for aspiration and penetration. Thin liquid penetration on SEES is moderately sensitive for predicting penetration on MBSS. Absence of thin liquid penetration or aspiration on SEES has a high NPV for excluding aspiration on MBSS. Abnormalities on SEES or the need to view the entire swallowing mechanism should prompt an MBSS for a more complete evaluation of dysphagia.

Level of Evidence: 4

KEYWORDS

aspiration, dysphagia, instrumental evaluation of swallow, screening

This work was completed at the Mount Sinai Health System, New York, NY, USA.

Poster presentation at the 101th Annual Meeting of the American Broncho-Esophagological Association, April 7-8, 2020.

1 | INTRODUCTION

The primary methods for evaluation of oropharyngeal dysphagia include the fiberoptic endoscopic evaluation of swallow (FEES) and modified barium swallow study (MBSS). MBSS involves fluoroscopic evaluation of swallowed radiopaque material of various consistencies and requires involvement of a radiologist and speech language pathologist. FEES involves visualizing the passage of food of various consistencies through the pharynx during swallowing using a transnasal endoscopic camera; this study typically requires involvement of multiple personnel including a speech language pathologist. Both studies may not be feasible in the typical otolaryngology visit due to the time and coordination required. Moreover, due to coronavirus precautions in the current era, availability of these studies may be restricted. Screening mechanisms for identifying those patients most in need of comprehensive swallow evaluation are critical.

Clinical bedside swallow evaluations, in which patients are given various consistencies to swallow and are monitored for clinical signs of aspiration and penetration, are a common method of screening for dysphagia; however, the sensitivity and specificity of this test vary widely depending on how many clinical signs are used for determining the presence of aspiration[1] with published estimates ranging from 0.65 to 0.86 and 0.30 to 0.96, respectively.[1-4] Additionally, clinical bedside swallow evaluations cannot distinguish between aspiration and penetration.

Recently, an alternative instrumental swallow examination technique, static endoscopic evaluation of swallow (SEES), was proposed in which the pharynx is examined without anesthesia with a transoral endoscope after swallowing various consistencies and was found to correlate significantly with findings of aspiration and penetration on MBSS in a study of 39 patients.[5]

As SEES offers evaluation of aspiration and penetration risk in clinic, it has the potential to be used as a screening test to identify the need for additional comprehensive evaluation with MBSS. Potential advantages of SEES over FEES procedures may include a shorter time to complete the evaluation as well as avoidance of topical anesthesia and disruption of nasopharyngeal closure during the swallow, factors thought to artificially increase rates of dysphagia detected by FEES.[6,7] Given the limited existing data regarding the sensitivity and specificity of SEES in the literature, we hope to further evaluate the diagnostic capability of SEES with regards to MBSS as the gold standard.

2 | MATERIALS AND METHODS

Approval from the Mount Sinai Committee on Human Research was obtained to perform a retrospective study of patients who underwent in-office SEES followed by MBSS for evaluation of dysphagia at Mount Sinai Hospital between 2017 and 2019. Patients who underwent evaluation for dysphagia were systematically identified using coding records of all patients who underwent MBSS. Patients who underwent SEES prior to undergoing MBSS were included in this study whether or not oropharyngeal dysphagia was ultimately identified. Exclusion criteria included lack of SEES video recordings or lack of stored MBSS images that would allow separate evaluation of the studies by raters specifically for research purposes. No swallow therapy was implemented between the SEES and MBSS evaluations.

SEES was performed by having patients swallow substances of various consistencies, including a sip of thin barium, a cup of thin barium, and a bite of cookie, followed by videoendoscopic evaluation of the hypopharynx and larynx with rigid transoral endoscopy. During the SEES, patients are instructed to "take a sip," "drink the entire cup," or "take a bite" of cookie and chew, and "then swallow once" to standardize the swallowing process and avoid multiple swallows. Endoscopy was performed immediately after each consistency was swallowed. Not all consistencies were tested in all patients per the judgment of the clinician at the time of the exam.

SEES and MBSS videos were collected and deidentified. SEES videos included four separate clips including clips prior to swallowing, after one sip of thin barium clip, after a cup of thin barium, and after a bite of dry solid. MBSS videos included two separate clips of swallowing including thin liquid and dry solid. 15% of the videos were repeated to allow for calculation of intrarater reliability.

Two raters (SKB and LG) evaluated SEES and MBSS videos independently in a blinded manner. Video clips including both SEES and MBSS clips were evaluated for presence and volume of residue at seven different anatomic subsites. Presence of residue was graded as absent or present. Volume of residue was graded as absent, trace/minimal, or moderate/maximal. The anatomic subsites included the valleculae, piriform sinuses, post-cricoid space, upper one third of the laryngeal vestibule, lower two thirds of the laryngeal vestibule, vocal folds, and trachea. As absence and presence of a finding cannot be averaged in cases where raters did not agree, one rater was selected at random to represent the "true" ratings and this set of ratings was used to calculate predictive values.

Inter- and intrarater reliability was calculated using weighted kappa. As kappa between 0.6 and 0.8 is considered substantial and above 0.8 is considered almost perfect,[8] only exam components with inter- and intrarater kappa above 0.6 were included in analysis. Additionally, exam subsites in which no patients had evidence of residue were excluded (Figure 1).

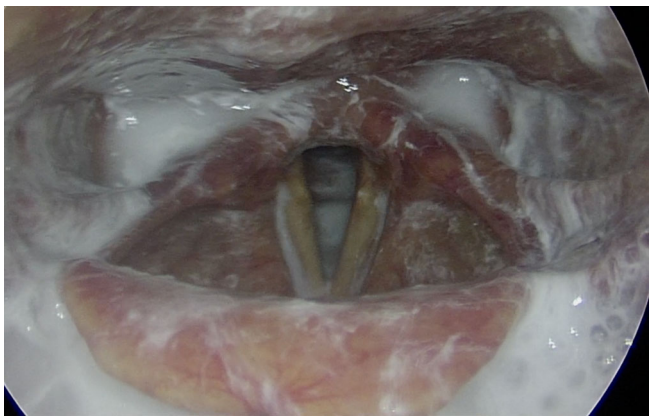

FIGURE 1 Aspiration identified on SEES after a swallowing a cup of thin barium

TABLE 1 Dysphagia diagnoses

Cranial nerve palsy		*Neurologic*	
Hypoglossal	2 (3%)	Oromandibular dystonia	1 (2%)
Vagal	2 (3%)	Stroke	2 (3%)
Recurrent laryngeal nerve	3 (5%)	Parkinsons	6 (10%)
		Traumatic brain injury	1 (2%)
Malignancy or treatment related			
Radiation induced fibrosis	13 (22%)	*Esophageal*	
Glottic cancer	1 (2%)	Cricopharyngeal bar	7 (12%)
Oropharyngeal surgery	1 (2%)	Zenker diverticulum	1 (2%)
		Stricture	5 (9%)
Other		Dysmotility	13 (22%)
Muscle tension	2 (3%)	Achalasia	1 (2%)
NLH	3 (5%)		
Osteophyte	1 (2%)		

Notes: Dysphagia diagnoses with total number and percentage of patients with each diagnosis. Values do not add up to 100% as some patients were given multiple diagnoses.
Abbreviation: NLH, neurogenic laryngeal hypersensitivity.

A combination of exam locations was used to determine penetration and aspiration. Exams were considered positive for penetration if residue was identified in the upper 1/3 of the laryngeal vestibule, lower 2/3 of the laryngeal vestibule, or on the vocal folds. Exams were considered positive for aspiration if residue was identified in the trachea. All of the applicable locations needed to be evaluated and noted to have no residue for an exam to be considered negative. Presence of residue in only one of the applicable locations was sufficient for an exam to be considered positive even if all of the applicable locations were not fully visualized. Exam locations that did not meet reliability cut-offs were not included in determination of penetration and aspiration. Findings from swallowing a sip and a cup of thin liquid on SEES were combined for analysis of predictive values and were reported as findings with thin liquid, as was performed in the original study on SEES.[5]

Additionally, time to complete the SEES exam was calculated from video time stamps. This measurement included time required to explain the exam to the patient, to allow the patient to swallow, and to perform an adequate endoscopic exam. This time does not include the pre-swallow endoscopic exam and does not include the time for SEES interpretation.

The Fisher exact test was used to determine statistical significance. Predictive values including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated. MBSS findings were used as true positives and negatives for calculation of predictive values. Statistical calculations were performed on Excel and R. Summary statistics are reported as means and standard deviations unless otherwise noted.

3 | RESULTS

Fifty-eight patients underwent SEES followed by MBSS for evaluation of dysphagia between 2017 and 2019. SEES videos included 58 pre-swallow, 55 sips of thin liquid, 43 cup of thin liquid, and 30 dry solid clips. MBSS videos included 57 thin and 47 dry solid clips. Average age was 60.7 ± 15.1 years old. 70% of the patients were men. Time between SEES and MBSS evaluations was 3.5 ± 2.4 weeks. Average time to evaluate three consistencies was 4.2 ± 2.8 minutes. Causes of dysphagia are listed in Table 1. Consistencies and locations that did not meet inter- and intrarater reliability are listed in Table 2.

Penetration of thin liquids on SEES had sensitivities and specificities of 0.86 (95% CI 0.70-0.95) and 0.63 (95% CI 0.24-0.91) for predicting penetration of thin liquids on MBSS, and 1.0 (95% CI 0.59-1.0) and 0.29 (95% CI 0.15-0.47) for predicting aspiration of thin liquids on MBSS. Aspiration of thin liquids on SEES had a sensitivity and specificity of 0.67 (95% CI 0.09-0.99) and 0.85 (95% CI 0.66-0.96) for predicting aspiration of thin liquids on MBSS (Table 3). PPV and NPV was calculated for various levels of disease prevalence to illustrate the predictive values of SEES in different hypothetical clinical populations (Table 4).

4 | DISCUSSION

SEES is highly sensitive for predicting aspiration of thin liquids on MBSS. Penetration of thin liquids on SEES had a higher sensitivity than aspiration of thin liquids for identifying aspiration that was later confirmed on MBSS, 1.0 vs 0.67, respectively. Specificity of SEES for predicting thin liquid aspiration on MBSS was moderate to low. At our institution this translated into a high NPV of 1.0 and low PPV of 0.23 when using absence of thin liquid penetration on SEES to exclude aspiration on MBSS.

On the other hand, SEES was only moderately sensitive and specific for predicting penetration of thin liquids on MBSS. Penetration of thin liquids on SEES had a sensitivity of 0.86 and specificity of 0.63 for predicting penetration of thin liquids on MBSS. Due to the high

prevalence of penetration in our patient group, the calculated PPV of SEES was moderately high at 0.91 for predicting thin liquid penetration on MBSS with a relatively low NPV of 0.5. Due to the retrospective nature of this study, the prevalence of penetration in our sample may be artificially high as those with no penetration on SEES are likely to forgo subsequent MBSS in our practice and would therefore have been excluded from this study.

TABLE 2 Inter- and intrarater reliability of exam subsites

	Consistency	Kappa ≥0.6	Kappa ≤0.6
MBSS	Thin	Vestibule, upper 1/3[a]	Valleculae
		Vocal folds[a]	Piriforms
		Trachea[a]	Post-cricoid
			Vestibule, lower 2/3[b]
	Solid	Valleculae[a]	Vestibule, upper 1/3
		Piriforms[a]	Vestibule, lower 2/3
		Post-cricoid[a]	Vocal folds[b]
			Trachea[b]
SEES	Sip of thin	Valleculae	Piriforms
		Vestibule, lower 2/3[a]	Post-cricoid
		Trachea[a]	Vestibule, upper 1/3
			Vocal folds
	Cup of thin	Valleculae	Piriforms
		Vestibule, upper 1/3[a]	Post-cricoid
		Vestibule, lower 2/3[a]	
		Vocal folds[a]	
		Trachea[a]	
	Solid		Valleculae
			Piriforms
			Post cricoid
			Vestibule upper 1/3
			Vestibule, lower 2/3
			Vocal folds
			Trachea

Notes: Subsites with inter- and intrarater kappa ≥0.6 are considered to have substantial or near perfect reliability, and were included in subsequent analysis. SEES sip and cup of thin consistencies were combined in subsequent analysis and reported as thin liquids.
[a]Degree of residue at this subsite also had inter- and intrarater kappa ≥0.6.
[b]No residue was identified on any of the patient exams.

Clearly, the prevalence of dysphagia varies between practices and the prevalence of dysphagia may even vary between different patient groups that present to the same practice. Predictive values were calculated for situations with different disease prevalence to adjust for these variations. In situations where disease prevalence is low, in other words in low risk groups, absence of thin liquid penetration on SEES may be used to exclude penetration and aspiration on MBSS. For example, in a population where prevalence of penetration is 10%, a SEES exam showing no thin liquid penetration has a high NPV of 0.98 for excluding penetration on MBSS. In a population where prevalence of aspiration is 10%, a SEES exam showing no thin liquid penetration has a high NPV of 0.97 for excluding aspiration on MBSS. On the other hand in patients with a clinical history that strongly suggests penetration or aspiration, MBSS may be warranted regardless of SEES findings given the lower NPV in higher risk groups.

Additionally, abnormalities noted on SEES warrant subsequent evaluation with MBSS. Due to relatively low PPVs, ranging from 0.2 to 0.7 for prediction of thin liquid penetration on MBSS and 0.12 to 0.82 for prediction of thin liquid aspiration on MBSS for disease prevalence between 10% and 50%, MBSS is important for confirmation of the findings noted on SEES. Moreover, MBSS provides more complete information regarding the swallow than SEES. Whereas SEES can only identify the presence or absence of penetration and aspiration, MBSS might identify specific processes during the swallow that are abnormal and that can be targeted for further treatment.

Clinically, SEES may be useful as a rapid instrumental evaluation of swallow that can provide immediate information regarding the swallow in routine clinic visits and which has value as a screening test. The average time required to explain the exam to the patient, have the patient swallow three consistencies, and perform an endoscopic exam of the hypopharynx and larynx after each of those consistencies was 4.2 minutes. However, this evaluation can be performed in less time if fewer consistencies are tested. Additionally, in this study the average time to obtain an MBSS was 3.5 weeks. SEES provided limited but expeditious information regarding the swallow that could be used to inform medical decision on the day of the clinic visit, as this procedure can be performed within the initial clinic visit by the evaluating physician. On the other hand, it does not provide the depth of information that is provided by MBSS or FEES.

In comparison to clinical bedside evaluation, SEES offers a number of advantages. More information regarding swallow pathology can be provided with SEES, including the ability to distinguish aspiration, penetration, and location of residue. Additionally, SEES sensitivity for

TABLE 3 Diagnostic accuracy of SEES for predicting MBSS abnormalities with thin liquids

SEES	MBSS	Sensitivity	Specificity	PPV	NPV	Prevalence
Penetration	Penetration	0.86 (0.70–0.95)	0.63 (0.24-0.91)	0.91 (0.76-0.98)	0.5 (0.19-0.81)	0.81
Aspiration	Aspiration	0.67 (0.09–0.99)	0.85 (0.66-0.96)	0.33 (0.04-0.78)	0.96 (0.79-1.0)	0.10
Penetration	Aspiration	1.0 (0.59–1.0)	0.29 (0.15-0.47)	0.23 (0.10-0.41)	1.0 (0.69-1.0)	0.17

Notes: Diagnostic accuracy of SEES for predicting MBSS abnormalities. SEES and MBSS findings describe thin liquid consistencies. Values reported with 95% confidence intervals.
Abbreviations: NPV, negative predictive value; PPV, positive predictive value.

TABLE 4 Predictive values for variations in prevalence

SEES	MBSS	Prevalence	PPV	NPV
Penetration	Penetration	10%	0.20 (0.11-0.35)	0.98 (0.95-0.99)
		30%	0.49 (0.31-0.68)	0.91 (0.82-0.96)
		50%	0.70 (0.52-0.83)	0.81 (0.66-0.91)
Aspiration	Aspiration	10%	0.33 (0.15-0.58)	0.96 (0.86-0.99)
		30%	0.66 (0.41-0.84)	0.86 (0.61-0.96)
		50%	0.82 (0.62-0.93)	0.71 (0.40-0.91)
Penetration	Aspiration	10%	0.12 (0.09-0.15)	0.97 (0.83-0.99)
		30%	0.36 (0.29-0.41)	0.88 (0.57-0.95)
		50%	0.57 (0.49-0.62)	0.76 (0.36-0.90)

Notes: SEES and MBSS findings describe thin liquid consistencies. Values reported with 95% confidence intervals.
Abbreviations: NPV, negative predictive value; PPV, positive predictive value;.

detecting aspiration is at the upper limit or higher than published bedside swallow sensitivity albeit with specificity at the mid to low range of published bedside swallow specificity. Disadvantages of SEES are that it requires endoscopic equipment and is more invasive compared to bedside swallow evaluations.

FEES is an alternative study that can be performed at bedside. However, studies have found higher rates of dysphagia detection on FEES compared to MBSS.[6,9,10] The higher rate of dysphagia detection may in fact be due to worsening of swallow during FEES rather than a higher sensitivity of FEES compared to MBSS. A randomized controlled trial by Adachi et al in which an MBSS was performed with and without an endoscope in place showed that endoscope placement increases the number of aspiration events and severity of pharyngeal residue.[6] Suggested etiologies include disruption of the normal swallowing process due to the topical anesthesia used for endoscope placement[7] or because of alteration of pharyngeal contraction and nasopharyngeal closure.[6] SEES avoids these theoretical reasons for creation of false positives as the swallow is performed without topical anesthesia and without an endoscope in place during the swallow.

Limitations of this study include exclusion of a number of exam subsites from analysis. This may be in part due to the relatively high kappa cut-off of 0.6. Prior studies examining inter- and intrarater reliability of MBSS have reported a similar range of kappa values including inter- and intrarater reliability of −0.16 to 0.56 and 0.24 to 0.90, respectively, for various pharyngeal subsites,[11-13] and interrater reliability of 0.56 to 0.57 and 0.39 to 0.89 for directed evaluation of penetration and aspiration, respectively.[11,12,14,15] Use of example videos as anchors to calibrate ratings between the two expert raters was not performed in this study and could be considered in future studies to increase reliability. Additional limitations include lack of standardization of MBSS boluses, evaluation of only single boluses on MBSS, the multiple week duration between SEES and MBSS in which the swallowing could have changed, and possible patient selection bias as patients with normal SEES may be more likely to forgo MBSS and therefore be excluded from this study. Future studies may consider direct comparison of SEES and FEES.

5 | CONCLUSIONS

SEES may be used as a rapid, objective test to screen patients for aspiration and penetration in the office. Penetration of thin liquids on SEES is moderately sensitive for predicting penetration on MBSS. Absence of thin liquid penetration or aspiration on SEES has a high NPV for excluding aspiration of thin liquids on MBSS. Abnormalities detected on SEES or the need to view the entire swallowing mechanism based on clinical presentation should prompt an MBSS for a more complete evaluation of dysphagia.

CONFLICT OF INTEREST

The authors declare no potential conflict of interests.

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How to cite this article: Chang J, Brown SK, Hwang C, Kirke DN, Goldberg L. Predictive values of static endoscopic evaluation of swallowing in adults. *Laryngoscope Investigative Otolaryngology*. 2021;6(6):1383-1388. https://doi.org/10.1002/lio2.615