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ORIGINAL ARTICLE

Improving the Diagnostic Capability of the Modified Barium Swallow Study Through Standardization of an Esophageal Sweep Protocol

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Abstract

The modified barium swallow (MBS) study is a videofluoroscopic evaluation of oropharyngeal swallow function. Esophageal imaging is not routinely performed during an MBS, and few guidelines for implementation or interpretation exist. Aims of the current investigation were to (1) delineate the percentage of normal, oropharyngeal, esophageal, and mixed swallowing dysfunction, (2) develop operational definitions for rating our standardization cursory view of esophageal bolus flow, and (3) determine inter-rater reliability between speech pathology (SLP) and physician raters for categorizing esophageal abnormalities. A two-phase retrospective review of 358 patient charts and MBS studies was conducted. Esophageal bolus flow was operationally defined as (1) normal, (2) anatomic abnormality, (3) dysmotility and (4) combined. Descriptive statistics, a Chi square with alpha set at 0.05, and Kappa analysis were performed. Esophageal dysfunction was identified in 80 (26%) patients and included: anatomic abnormality (69%), dysmotility (17%), and combined abnormality (14%). Phase one reliability testing yielded fair agreement between SLP and MD raters $k = 0.5$. Following revision of definitions and consensus training, phase two reliability testing resulted in excellent agreement between the same raters $k = 0.9$. Multiphase or primary esophageal dysphagia was found in 26% of our sample using a standardized protocol rating esophageal bolus flow from the upper esophageal sphincter through the lower esophageal sphincter during the MBS. Improved agreement between SLP and MD raters after definition revision and training suggests these operational definitions are concise, objective and reliable. An expanded MBS study may lead to early identification of esophageal disorders, encourage multidisciplinary patient care, and improve patient health outcomes.

Keywords Esophageal dysphagia · Oropharyngeal dysphagia · Esophagus · Screening · Protocol · Deglutition · Videofluoroscopy

Introduction

Swallowing is a complex, continuous multiphase process that spans the oral cavity to the stomach. Dysphagia, or difficulty swallowing, is a symptom of underlying disease and can present as impairment in one or more phases of swallowing. However, traditionally swallowing assessment is dichotomized into oropharyngeal and esophageal evaluation. The modified barium swallow (MBS) study is a videofluoroscopic evaluation of oropharyngeal swallow function performed by a speech language pathologist (SLP) and physician. It dynamically captures bolus flow in the upright position from the oral cavity to the cervical esophagus [1]. Visualization of the entire esophageal phase with various bolus textures (i.e., liquid, solid, and tablet) may not be routinely performed in clinical practice.

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Accurate identification of dysphagia etiology can be challenging. Many common medical conditions may have multiphase swallow impairment including achalasia [2], diabetes [3], scleroderma [4], gastroesophageal reflux disease [5–7], and Parkinson's disease (PD) [8, 9]. Adequate history taking can determine the anatomical location of dysphagia (i.e., oropharyngeal or esophageal) approximately 80% of the time or less; a patient's report of symptoms does not always accurately identify the phase of swallowing deficit [10, 11]. It has been shown that patients are more accurate in identifying the location of proximal dysphagia than distal problems [12]. Therefore, up to one-third of patients who complain of lower throat symptoms may actually have an esophageal cause for dysphagia [13].

Oropharyngeal and esophageal disorders can coexist. Eighty-seven percent of head and neck cancer survivors with oropharyngeal dysphagia may have a co-occurring esophageal pathology [14]. Oropharyngeal dysfunction is present in patients with esophageal motility disorders, and esophageal motor dysfunction is found in patients with oropharyngeal dysphagia [15]. There are documented temporal and physical interactions between the oropharynx and esophagus [16, 17]. Gullung et al. [16] reported that abnormal bolus flow through the esophagus correlated with delayed initiation of swallowing in the oropharyngeal phase [16]. Lever et al. [17] reported that using an effortful swallow to increase pharyngeal pressures also increased lower esophageal body peristaltic amplitude.

Since swallowing is a multi-phase phenomenon, swallowing evaluation should be comprehensive across all phases. This is not always the case as dysphagia assessment often occurs in isolation [18]. However, the Modified Barium Swallow Impairment Profile (MBSImp) is evidence based, standardized, and visualizes all phases of swallowing when possible. This protocol follows both a 5 cc. nectar-thick liquid and a 5 cc. barium paste through the LES. Bolus clearance is then assigned an objective rating score of 1–4 [19]. Since development, authors have compared associations between impairment scores on the MBSImp and physiologic outcomes on intraluminal impedance esophageal manometry [20]. Results of this study showed that 78% of patients with functional abnormality on manometry also showed impairment on the esophageal component of the MBSImp. Of note, in this retrospective design, only patients who underwent both procedures were included for analysis. As such it is difficult to determine the false negatives in this sample. These standardized assessments and data provide vital information regarding the need for a protocol to ensure consistent and repeatable interpretation of exam results.

Despite past research efforts to establish the benefits of esophageal view of bolus flow during the MBS, there is a paucity of data on implementation of a robust (liquid, solid, and tablet), standardized, and easily interpreted protocol following a bolus through the esophagus and into the stomach. Furthermore, there is some hesitancy to perform the sweep, as there is a gap in the standardization and reporting of abnormalities. This gap may delay identification of a previously undetected esophageal disorder and negatively impact treatment outcomes for individuals with multiphase dysphagia. Given the diverse patient referral base and standardized esophageal sweep protocol already used within our practice setting, the aims of the current investigation were to (1) delineate the percentage of normal, oropharyngeal, esophageal, and mixed swallow dysfunction in our cohort as identified by our clinical interpretation of the modified barium swallowing study (2) develop operational definitions for rating our standardized cursory view of esophageal bolus flow, and (3) determine inter-rater reliability between SLP and physician raters for categorizing esophageal abnormalities.

Methods

A two-phase retrospective chart and swallow study database review was approved by the Institutional Research and Ethics Committee at the University of South Florida (USF) under protocol number 00026367. Two phases were implemented to allow for discrepancy meetings, revision of definitions as needed and, the addition of swallowing studies for analysis. The USF Joy McCann Culverhouse Center for Swallowing Disorders is a university-based tertiary care center with a dedicated swallowing staff including two gastroenterologists who specialize in esophageal dysphagia, two SLPs, one registered nurse (RN), two medical assistants and administrative support staff all geographically located together. Referral base for modified barium swallowing studies includes otolaryngology, pulmonology, neurology, gastroenterology, internal medicine, allergy, and rheumatology. When a patient is referred for an MBS from any provider, a standardized esophageal sweep protocol is routinely implemented at our Swallowing Center. This is not implemented when it is deemed unsafe for a patient (i.e., significant aspiration on the MBS study) or there are significant positioning limitations and an anterior–posterior (AP) view cannot be obtained.

Multidisciplinary assessment and treatment is provided for a range of swallowing disorders including oropharyngeal dysphagia resulting from neurogenic disease, head and neck cancer management, surgery, functional disorders, and esophageal etiologies. Common esophageal disorders treated at the USF Swallowing Center include achalasia, simple and complex strictures, connective tissue disease, eosinophilic esophagitis, and gastroesophageal reflux disease. Patients travel from throughout Florida and the Southeastern U.S. to receive services.

The current protocol was carried out through systematic review of consecutive MBS studies performed at our Swallowing Center from June 2015 through August 2016. Phase one of the study included review of 205 MBS studies. Following revision of operational scoring definitions, an additional 153 MBS studies were also included for the analysis. For phase two of the study, at least four months following initial review, MBS studies were randomized and all the studies from phase one were re-rated with revised operational definitions for a total review of 358 swallowing studies. We hypothesized that a large portion of our cohort would present with multiphase dysphagia and rater agreement would improve with use of concise operational definitions.

Participants

MBS studies were reviewed; study exclusion criteria were as follows: (1) inability to complete the esophageal sweep protocol; this refers to patients with aspiration risk for large bolus swallows and positioning limitations who did not undergo the sweep protocol during evaluation and (2) previous enrollment in a research study that excluded esophageal observation from the protocol. From chart review, patient demographics (age, gender, and primary medical diagnosis) and instrumental esophageal testing outcomes were collected. When available, results from previous esophageal testing was recorded and included high-resolution esophageal manometry, endoscopy, barium esophagram or timed barium emptying study to confirm findings from the MBS study.

Materials and Procedures

Videofluoroscopic swallowing assessment was performed in the Swallowing Center by a speech pathologist that is jointly licensed to provide radiology technician services under direct physician supervision. Videofluoroscopic images were obtained in both lateral and AP viewing plane using a Philips BV Endura fluoroscopic C-arm unit (GE OEC 8800 Digital Mobile C-Arm system type 718074). The swallowing examinations were recorded at a video scan rate of 29.98 frames per second using the Digital Swallowing Workstation (model 7120; Pentax; Lincoln Park, NJ). Images were then stored on the Center's database for subsequent analysis. MBS was completed using a range of textures and volumes in lateral and AP view with compensatory strategies introduced as needed to make oropharyngeal diagnoses and recommendations.

Judgments of bolus flow through the esophagus were made in AP view during four swallows: (1) one-fourth of a graham cracker coated with 5 cc. barium paste (Varibar 40% w/v, EZ EM Bracco diagnostics Monroe Twp., NJ); (2) 13-mm barium tablet (E-Z-Disk 700 mg.); (3) one large (uncontrolled volume) patient administered swallow of barium contrast (E-Z-Paque 70% w/v) imaged passing the length of the esophagus and; (4) one large (uncontrolled volume) patient administered swallow of barium contrast imaged at the lower esophagus and assessed passing through the lower esophageal sphincter (LES). If there was a delay in bolus passage, brief views were obtained at 30 and 60 s. If barium contrast did not clear at 60 s, a sip of water was provided and results were recorded. See Table 1 for the protocol.

Two blinded raters, an SLP and gastroenterologist, reviewed all swallowing studies. Both raters were blinded to patient demographic and diagnostic information. SLP reviewing studies had greater than 30 years of experience performing and interpreting MBS studies. The gastroenterologist had extensive swallowing specialization training. The SLP reviewed the entire MBS and rated the oropharyngeal swallow as normal or abnormal using clinical judgment. Both the SLP and gastroenterologist independently rated the four esophageal sweep swallows [solid, 13 mm barium tablet and (2) liquid swallows] using operational definitions; see Table 2. All four swallows had to be scored as normal to achieve a rating of normal. Otherwise they received a rating of anatomic abnormality, dysmotility or combined abnormality.

Phase One

An initial review of 205 MBS studies was carried out using phase one esophageal classification definitions (Online Appendix). Descriptive analysis was performed; distribution and relative frequency for qualitative measures were derived (mean, standard deviation, and minimum and maximum values). Cohen's Kappa coefficient analysis was performed for inter-rater reliability (between rater 1 and rater 2). Alpha was set at 0.05; Kappa values of >0.8 were deemed as "substantial".

Phase Two

Phase two of the study included informal discrepancy meetings held to revise operational definitions for clarity, brevity, and improvement in objectivity of observations. The final arbiter was a senior gastroenterologist (JR) with 35 years of experience with EGD and barium radiology studies. Previous research has shown up to a 1 min transit time for normal bolus passage; (2–60 s for 20 mL of liquid, 1–60 s for a 13-mm tablet and, 4–60 s for barium paste) [21]. Given previous investigations of esophageal transit times in healthy older adults, phase two definitions were altered for clarity by allowing for an upward limit of 60 s for bolus flow time for each bolus type (Table 2). Blinded SLP and

Table 1 Esophageal sweep protocol including bolus presentation, patient instruction, and imaging protocol

Bolus presentation	Patient instruction	Imaging
¼ Graham cracker with 5 cc. barium paste	Chew the cracker as much as you need and indicate before you are going to swallow.	Dynamically follow bolus from the pharynx to the stomach. Stop imaging and wait 30 s. Re-image at 30 s. Re-image at 1 min.
Patient administered cup sip of barium liquid (E-Z-Paque 70% w/v)	Take one large sip (uncontrolled volume) and hold it in your mouth. Only swallow one time.	Dynamically follow bolus from cervical esophagus to LES. If bolus is retained, stop imaging and wait 30 s. Re-image at 30 s. Re-image at 1 min.
Patient administered cup sip of barium liquid (E-Z-Paque 70% w/v)	Take one large sip (uncontrolled volume) and hold it in your mouth. Only swallow one time.	Dynamically follow bolus from lower esophagus to stomach. If bolus is retained, stop imaging and wait 30 s. Re-image at 30 s. Re-image at 1 min.
13-mm. Barium tablet	Take the barium tablet with as much water as you need.	Dynamically follow tablet from oral cavity to the stomach. If bolus is retained, stop imaging and wait 30 s. Re-image at 30 s. Re-image at 1 min.

gastroenterologist raters re-assessed all 205 phase one swallow studies. An additional 153 patient swallow studies were added for a total of 358 MBS swallowing evaluations using the edited operational definitions.

Results

Phase One

Two hundred and five MBS studies were reviewed. Twenty-two patients (10%) were excluded from total sample analysis ($n = 183$). Exclusion from review included (1) inability to complete the esophageal sweep protocol; this refers to patients with aspiration risk for large bolus swallows and positioning limitations and (2) previous enrollment in a research study that excluded esophageal observation from the protocol. Mean age of the final sample was 61 years (range 17–95 years), and 54% of the sample was female. The distribution of swallow dysfunction was as follows: oropharyngeal dysphagia (89/183) 48.6%, normal oropharyngeal swallow (41/183) 22.4%, both oropharyngeal and esophageal impairment (30/183) 16.4%, and esophageal impairment only (23/183) 12.6%. Using the sweep protocol and operational definitions, esophageal dysfunction was identified in 53 patients (28.9%) who underwent an MBS. There was fair agreement between SLP and MD raters $k = 0.5$ (0.63–0.37).

Phase Two

After the discrepancy meeting, additional swallowing studies were added for review; a total of 358 MBS studies were in the cohort for review including 205 original MBS studies plus 153 additional MBS studies. Fifty-one patients (14%) in total from both group one and two were excluded from the total sample analysis ($n = 307$). Exclusion criteria was the same as phase one of the study and included: (1) inability to complete the esophageal sweep protocol; this refers to patients with aspiration risk for large bolus swallows and positioning limitations and (2) previous enrollment in a research study that excluded esophageal observation from the protocol. Mean age of the final sample was 60 years of age (range 15–95 years), and 54% of the sample was female. The distribution of swallow dysfunction was as follows: oropharyngeal dysphagia (156/307) 51%, normal oropharyngeal swallow (71/307) 23%, both oropharyngeal and esophageal impairment (43/307) 14%, and esophageal impairment only (37/307) 12% (Fig. 1). There was excellent agreement between the same raters $k = 0.9$, (0.85–0.95).

Using the revised operational definitions, esophageal dysfunction was identified in 80 (26%) patients, x^2 (3) = 117, $p < 0.05$. Categorically, anatomic abnormality was the most

Table 2 Phase two, final operational definitions used to determine normal versus abnormal bolus flow through the esophagus in the upright position for a solid bolus, liquid boluses, and a 13-mm barium tablet

Category	Operational definitions
Normal	*Solid*: Complete clearance of solid through esophagus within 1-min ± liquid wash. *Pill*: Passage through esophagus and LES within 1-min ± liquid wash. *Liquid*: Straight proximal to distal movement of bolus with inverted "v" shape stripping wave within 1 min.
Anatomic abnormality	*Solid*: Any deviation of solid bolus flow through the esophagus. *Pill*: Pill hang-up at any location proximal or distal despite liquid swallows after 1 min. *Liquid*: Tapering of liquid barium column when esophagus is maximally dilated, deviation of straight esophageal contour or deviation of liquid bolus flow.
Dysmotility	*Solid*: Disordered wave propagation resulting in retention of bolus > 1 min and following a liquid wash. *Pill*: Retrograde movement of pill within the esophagus > 1 min. *Liquid*: Disordered wave propagation resulting into and fro bolus movement or non-peristaltic contractions with retention > 1 min.

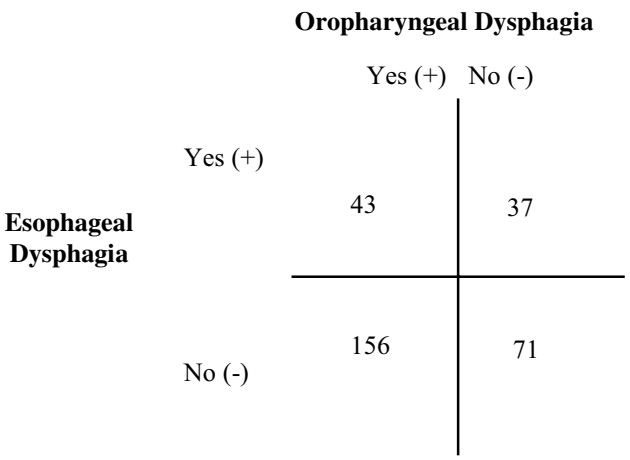

Figure 1 Contingency table of dysphagia type based on 307 modified barium swallow studies; 51 studies were excluded from initial review based on incomplete sweep protocol

common classified finding at 69% of the sample followed by dysmotility (such as retrograde bolus movement and obvious tertiary contractions) at 17% and a combined impairment at 14% (Fig. 2). When possible, additional esophageal testing confirmed the suspected etiology of esophageal dysphagia identified on MBS with appropriate standard esophageal testing including: high-resolution esophageal manometry, endoscopy, or timed barium esophagram. Of the 80 suspected esophageal abnormalities detected on the MBS sweep protocol, 42 patients (52.5%) had undergone additional esophageal testing. From this additional testing, all 42 instances were found to have esophageal abnormality on gold standard testing. The following final diagnoses were made: achalasia/outflow obstruction ($n = 8$), stricture ($n = 15$), combination of esophageal findings ($n = 12$), and hiatal hernia ($n = 7$). See Table 3. for information on follow-up and subsequent treatment plan.

Discussion

Swallowing is a continuous process, usually divided into four overlapping phases [1]; evaluation of swallowing is traditionally dichotomized into oropharyngeal and esophageal assessment. A growing body of literature supports the inter-related swallowing systems and potential benefit of assessing swallow function more comprehensively; from the mouth through the esophagus into the stomach. This study employed a systematic and standardized cursory view of bolus flow through the esophagus during the MBS; we identified that one in four patients (26%) had an esophageal cause for their dysphagia, and this swallowing abnormality would have gone undetected in the standard MBS without esophageal observation. Over half of patients identified had confirmed esophageal etiologies with standard esophageal testing and underwent subsequent medical treatment such as upper endoscopy with dilation, pneumatic dilation, or were referred for a surgical consult.

Development of clear, concise, and objective operational definitions to classify normal versus abnormal bolus flow through the esophagus in the upright position resulted in improved inter-rater reliability ($r = 0.916$) between physician and SLP raters. Although this study does not show a cause and effect relationship between identification of disorder and timely management, in most cases patients received a prompt GI physician evaluation, additional diagnostics and appropriate management for an otherwise undetected esophageal swallowing problem.

It is widely accepted that many common diseases have multiphase swallow impairment, and despite adequate history taking, it can be difficult to localize the level of dysphagia by history and physical alone. Current research supports multi-phase swallowing assessment, as previous investigations have reported the utility of a cursory esophageal phase assessment. The MBS study is often a preferred examination of oropharyngeal swallowing function as this assessment allows for capturing complete images from the oral cavity

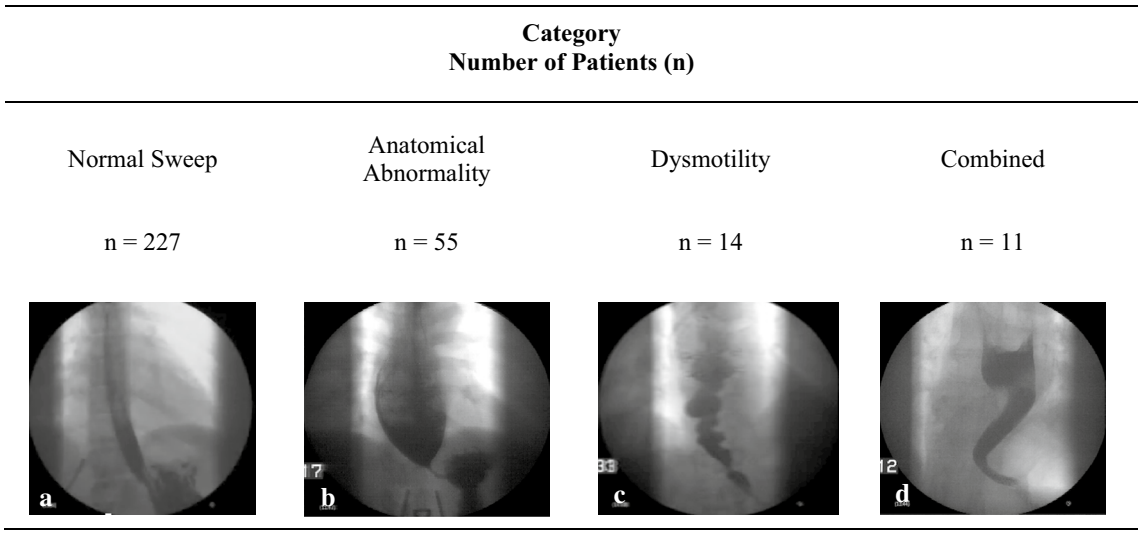

Figure 2 Static images from the modified barium swallow study esophageal sweep. **a** Normal esophageal sweep; inverted "v" shape with passage through the LES. **b** Anatomic abnormality showing tapering of barium which limited bolus passage through the LES due to achalasia (confirmed by manometry). **c** Disordered wave propagation; bolus was retained > 1 min. **d** Deviation of bolus flow with tapering of barium column and proximally, disordered wave propagation

Table 3 Diagnostic findings identified by category of abnormality on the modified barium swallow study and confirmed diagnosis with instrumental evaluations. Also, listed are medical management findings from the retrospective chart analysis

Sweep category	MD diagnosis confirmed[a]	(*n*)	Management	(*n*)
Anatomic abnormality	Stricture	15	No follow up[b]	3
			Dilation	11
			Surgery	1
	Achalasia/outflow obstruction	8	Botox	3
			Pneumatic dilation	1
			Surgery	2
			No follow up[b]	2
	Hiatal Hernia (HH)	7	Surgery	3
			Medication (PPI)	1
			No follow up[b]	3
Dysmotility	Hypercontractile	0	N/A	N/A
	Hypocontractile	5	Medication (PPI)	1
			Behavioral strategies	2
			No follow up[b]	2
Combined	Esophageal diverticulum/stricture/large HH	7	No follow up[b]	1
	Dysmotility/web		Dilation/botox	1
	Weak peristalsis/stricture		Dilation	1
	HH/tortuous esophagus/shelf compression/dysmotility		Referred for surgery	1
	HH/ZD/reflux		NPO until follow up	1
	Post-surgical anatomy/dilated esophagus		No follow up[b]	1
	TE fistula and stricture		Admit to hospital	1
Total		42		

MD medical doctor, *TE* tracheoesophageal, *ZD* Zenker's diverticulum, *NPO* Nil per os (nothing by mouth), *PPI* proton pump inhibitor, *HH* hiatal hernia

[a]Confirmed diagnosis as determined by one or a combination of the following instrumental evaluations: high-resolution manometry, time barium emptying study, esophagogastroduodenoscopy and barium esophagram

[b]No follow up includes the following scenarios: Patient passed away from unrelated circumstance, patient received treatment closer to residence, and patient was seen as consult only and went back to referring physician with recommendations for additional imaging/evaluation

through the upper esophageal sphincter and also allows for opportunity to view the esophageal aspect of swallowing. However, there are few guidelines for implementation of esophageal observations that could enhance the diagnostic capability of the study [22]. Current guidelines set forth by The American College of Radiology indicate the following, "a complete patient evaluation may also include spot images of the pharynx for structural assessment and an esophagram, as symptoms of dysphagia are often poorly localized" [25].

The utility of adding an esophageal component to the MBS has been explored [23, 24]. Allen et al. [23] reported sensitivity, specificity, and predictive values of esophageal "screening" or cursory assessment during the MBS in comparison to a full esophagram [25]. Screening was completed with one 20 mL bolus followed through the length of the esophagus. The authors reported that the specificity of the screen was high (100%), however, sensitivity was limited (62.8%); an abnormal screen was 100% predictive of an abnormal esophagram result [23]. They also indicated that the addition of a 13-mm barium tablet would have improved the sensitivity to 71%. More recently, Miles et al. [24] reported the prevalence of esophageal abnormalities identified during the MBS with one 20 mL liquid swallow and 13 mm barium tablet. Abnormal esophageal transit was identified in 68% of the total sample [24].

These authors support the use of an esophageal sweep during the MBS study, and there is consensus that a protocol including various bolus textures is needed. However, current guidelines to facilitate implementation are lacking. Recently, Miles et al. [24] reported substantial agreement among SLP raters judging esophageal abnormality during the MBS [26]. Given objective guidelines and additional training, the SLP has the unique opportunity to improve the diagnostic accuracy of the MBS by adding a standardized esophageal sweep protocol to the routine MBS assessment.

There is growing evidence and support for a modernized MBS study. There are several procedural, industrial, and educational limitations which impact implementation of a robust view of bolus flow through the esophagus during an MBS. *The American College of Radiology* has endorsed a view of the esophagus during the MBS [25]; however, they do not indicate protocol specifications. Some insurance companies (Medicare) limit payment for same day services for MBS and barium esophagram; therefore, if the physician is unsure of the etiology of a patient's swallow complaints, a modified barium swallow study and barium esophagram cannot be performed at the same time. Additionally, there are radiologist concerns regarding liability, documentation, and billing for additional esophageal imaging during the MBS.

The American Speech Language and Hearing Association, the national credentialing organization for speech pathologists, endorses cursory assessment of the esophageal phase of swallow during videofluoroscopic assessment, but offers no specific implementation recommendations [25]. Although they endorse a screen, they do not define criterion or a protocol. A "screen" implies a pass/fail standard, but greater interpretation of esophageal bolus flow may be needed.

Barium studies have been considered a "dying art." According to Levine, [27] there has been a sharp decline in barium imaging studies performed due to increased use of endoscopy and advanced imaging techniques, relatively low reimbursement rate, perception of barium studies as "low tech" imaging, and labor-intensive workforce [27]. The resulting impacts include difficulty maintaining skills for high-quality studies, lack of fluoroscopy training for new residents, and higher healthcare costs for advanced imaging technology.

Although the use of barium studies is in decline within the gastroenterology practices, the MBS remains the preferred choice of assessment due to the ability to perform a more comprehensive view of anatomy and physiology above other imaging techniques such as pharyngeal manometry and fiberoptic endoscopic evaluation of swallowing (FEES). Additionally, the MBS is widely used by SLPs in healthcare settings. Therefore, speech pathologists have the skill set to expand the MBS to include a cursory view of esophageal bolus flow and identification of important anatomic abnormalities. The cursory view of bolus flow through the esophagus during an MBS is not intended to replace the air contrast barium esophagram. However, performing the sweep using a protocol including multiple bolus textures (liquid, solid, and tablet) provides a unique opportunity to identify obvious abnormalities that may be contributing to the patient's dysphagia complaint simultaneous with oropharyngeal evaluation, and provide additional information for further workup. A robust esophageal sweep protocol may allow for more rapid referral of patients to upper endoscopy to evaluate structural abnormalities and high-resolution manometry with impedance to evaluate impaired bolus clearance and identify achalasia or other major esophageal motility disorders such as diffuse spasm.

Given that oropharyngeal and esophageal swallowing processes are inter-related, the purpose of the sweep is to view the swallowing problem in context of the entire swallow process with clinically certified specialists who are actively diagnosing oropharyngeal dysfunction. This "modernized MBS" may reduce the risk that the etiology of a swallow complaint goes undetected and thus untreated. It is a simple, easily reproducible, efficient addition to the MBS study that has a high diagnostic yield. The clear operational definitions used in this study frequently identified esophageal abnormality and had high inter-rater reliability that may be adopted in a variety of healthcare settings. Our MBS sweep provided

preliminary and exciting findings, however, there are several limitations and future needs.

Limitations and Future Direction

The setting for this investigation was a tertiary center for swallowing evaluation. This Center serves patients with a multitude of both oropharyngeal and esophageal disorders. Given the setting, it potentially increases the diagnostic yield of the esophageal sweep findings. Additionally, the population served includes only outpatients. Typically these patients are more mobile, oriented, and able to follow multi-step commands needed to complete the sweep protocol than individuals in an inpatient setting. These methodological variables may decrease the generalizability of a robust esophageal sweep to other practice settings. A prospective investigation on the feasibility of implementation of this sweep, percentage of esophageal findings in an inpatient setting, and the reliability of SLP ratings using our definitions is being implemented.

This preliminary investigation was aimed at delineating the breakdown of multiphase dysphagia seen at our Center as identified on initial MBS testing, determining a set of definitions for abnormal esophageal bolus flow that could easily be interpreted by a speech pathologist, and determining the reliability between speech and physician (esophagologist) raters. The attending physicians in our practice are gastroenterologists; future studies should determine reliability of ratings between speech pathology raters with varying degree of swallowing expertise as well as speech pathologists and radiologists.

The retrospective nature of the study design did not allow for calculation of sensitivity and specificity of the sweep protocol. It would be beneficial to implement a prospective study and to confirm esophageal abnormalities detected on the sweep in all patients with standard esophageal testing to determine true indication of disease and calculate the presence of treatable disease. Although a cursory view of esophageal bolus flow in the upright position may be considered "normal", this does not exclude esophageal pathology. Patients with complaints of dysphagia should undergo additional workup as deemed necessary by the physician.

Author Contributions SW Study concept and design; acquisition of data; drafting of the manuscript; statistical analysis, JG Data analysis, manuscript preparation, JJ Data analysis, JR Study concept and design, study supervision; critical revision of the manuscript for important intellectual content.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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