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Review Article

Best Practices in Modified Barium Swallow Studies

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Purpose: The modified barium swallow study (MBSS) is a widely used videofluoroscopic evaluation of the functional anatomy and physiology of swallowing that permits visualization of bolus flow throughout the upper aerodigestive tract in real time. The information gained from the examination is critical for identifying and distinguishing the type and severity of swallowing impairment, determining the safety of oral intake, testing the effect of evidence-based frontline interventions, and formulating oral intake recommendations and treatment planning. The goal of this review article is to provide the state of the science and best practices related to MBSS.
Method: State of the science and best practices for MBSS are reviewed from the perspectives of speech-language pathologists (SLPs) and radiologists who clinically practice and conduct research in this area. Current quandaries and emerging clinical and research trends are also considered.
Results: This document provides an overview of the MBSS and standards for conducting, interpreting, and reporting the exam; the SLPs' and radiologist's perspectives on standardization of the exam; radiation exposure; technical parameters for recording and reviewing the exam; the importance of an interdisciplinary approach with engaged radiologists and SLPs; and special considerations for examinations in children.
Conclusions: The MBSS is the primary swallowing examination that permits visualization of bolus flow and swallowing movement throughout the upper aerodigestive tract in real time. The clinical validity of the study has been established when conducted using reproducible and validated protocols and metrics applied according to best practices to provide accurate and reliable information necessary to direct treatment planning and limit radiation exposure. Standards and quandaries discussed in this review article, as well as references, provide a basis for understanding the current best practices for MBSS.

The modified barium swallow study (MBSS) is a widely used videofluoroscopic evaluation of the functional anatomy and physiology of the swallowing mechanism, swallowing efficiency, and airway protection. The information gained from the examination is critical for identifying and distinguishing the type and severity of physiological swallowing impairment, determining the safety of oral intake, testing the effect of evidence-based frontline interventions, and formulating oral intake recommendations and treatment planning. The American College of Radiology (ACR) practice parameters endorse the use of the term "MBSS" to describe this evaluation (ACR, 2017). It is important to note that different consumer and professional organizations use other terminology to describe this examination. In pediatrics, the equivalent and commonly used term is "videofluoroscopic swallow study" (VFSS). For the purpose of this review article, we will use the terminology interchangeably in the respective sections.

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Accurate diagnostic information attained from the MBSS, when paired with other clinical evaluations, patient history, and clinician judgment, provides the basis for determining a patient's physiological swallowing diagnoses. The MBSS is also used to identify the physiological targets for behavioral intervention that improve swallowing function. Use of a standardized, reliable, and valid protocol for acquiring and reviewing videofluoroscopic images is commonly considered best practice. It is also important to understand how accuracy may be influenced by technical parameters of the examination and to select the proper settings and requirements for the fluoroscopy unit and recording and playback devices.

A risk/benefit analysis must be made related to patient safety in terms of aspiration events, as well as patient and clinician safety related to radiation exposure. Safety concerns may dictate whether an MBSS is indicated and how the examination is performed (e.g., protocol use, technical parameters). The risk/benefit analysis should be based on scientific evidence, pathophysiological reasoning, and clinical experience (Tonelli et al., 2012).

Lastly, it is critical to consider the resources used for MBSS, including, but not limited to, clinician and physician training and time; efficiency and infection control issues in the fluoroscopy suite; acquisition, recording, and playback equipment; and guidelines for provider supervision. It is important to consider that MBSS best practices will often impact care not only in the inpatient/hospital setting, where the MBSS is often performed, but also in the rehabilitation, long-term care, home health, and outpatient settings where the results from the exams may be used.

Collaboration between the radiologist and speech-language pathologist (SLP) assures optimized performance of the MBSS and best care for the patient. As such, this tutorial presents a series of essays by five experts who represent the interdisciplinary nature of this topic The goal of this review article is to provide the state of the science related to three main requisites of best practices: (a) acquisition of essential diagnostic information, (b) adherence with patient and clinician safety recommendations, and (c) technical standards and resource utilization.

MBSS Purpose, Composition, and Standards for Conducting and Interpreting the Examination in Adults

Dr. Bonnie Martin-Harris

The primary goals of the MBSS are to (a) identify and distinguish the presence, type, and estimated severity of physiological swallowing impairment; (b) determine the safety (airway protection) and efficiency (clearance) of oral intake; (c) detail the effects of frontline interventions (postures, maneuvers, bolus variables) on swallowing physiology, airway protection, and efficiency; (d) develop targeted, therapeutic interventions when appropriate for the clinical condition of the patient; and (e) develop intake and nutritional management plans in collaboration with the physician and interdisciplinary team. Each goal is inherent in the overall purpose of the MBSS, and no single goal is sufficient for describing a swallowing disorder, which represents a multifactorial and complex health condition. For example, identifying only the presence of risk factors, such as aspiration and residue, without sufficient details of swallowing physiology minimizes the purpose of the exam and the complexity of the swallowing mechanism and ignores the underlying and often treatable cause of these risk factors.

An MBSS is conducted when a patient is referred by a physician based on a dysphagic complaint or clinical evidence consistent with a potential swallowing abnormality signaling pulmonary or nutritional risk. An MBSS should ideally involve an SLP certified by the American Speech-Language-Hearing Association (ASHA) and a radiologist who has received specialized training and established expertise in the assessment of oropharyngeal and cervical esophageal swallowing function and impairment (ACR, 2017).

Evolution From Variable to Standard Best Practices

The original and current intent of the MBSS is to (a) identify the physiology of the swallowing mechanism (Dodds, Logemann, & Stewart, 1990; Dodds, Stewart, & Logemann, 1990; Donner, 1985; B. Jones et al., 1985; Martin-Harris et al., 2000; Ramsey et al., 1955), (b) identify signs of risk for airway safety (penetration/aspiration) and swallowing efficiency (residue; Kahrilas et al., 1992; Robbins et al., 1999; Rosenbek et al., 1996), and (c) test the immediate effects of compensatory strategies toward improvement in (a) and (b) (Dantas et al., 1990; Ekberg, 1986; Ekberg et al., 1988; Kahrilas & Logemann, 1993; Kahrilas et al., 1991; Logemann, 1999; Logemann et al., 1989; Martin et al., 1993). The MBSS is not an assessment of feeding, but rather an examination that details the physiological function of the swallowing mechanism. A well-trained and experienced clinician should logically apply interventions (postures, strategies, bolus volume, and consistency modifications) during the examination based on the clinical status and swallowing performance of the patient. These interventions are to be applied only when evidence supports their effect on the identified impairment and with consideration for patient and operator safety and examination efficiency.

The Protocol

Consistent with other radiographic examinations, the MBSS should employ a protocol characterized by validated core elements or standards that allow transparency, interoperator reproducibility, accurate and reliable measurements, and clear consumer (patients, physicians, clinicians) expectations regarding the procedure and outcomes of the examination. Within the context of these core elements, there should be flexibility for reasonable modification based on the clinical circumstances of the patient or specific clinical questions that may need to be addressed using rationally applied, empirically based interventions.

Barium sulfate suspension is the contrast agent used in boluses of thin and thick liquids, semisolids, and solids to allow visualization of liquids and foods simulating those on a patient's meal tray (Dantas et al., 1989; Robbins et al., 2002). A standardized set of barium sulfate preparations or consistencies have been developed currently for distribution in the United States, are FDA approved, and are specifically labeled for MBSS (VARIBAR barium sulfate 40% weight/volume, Bracco Diagnostics, Inc.). While this set of consistencies does not represent the full and nearly endless complement of consistencies that may appear in real-life foods and liquids, they are mapped to Levels 0 and 2–4 on the International Dysphagia Diet Standardization Initiative and used in the development of standardized, validated measures of swallowing physiology (Hazelwood et al., 2017; Hind et al., 2012; Lam et al., 2017; Martin-Harris et al., 2008, 2017). While factory-produced, standardized barium sulfate preparations are not available in all countries, resources are available to clinicians for preparing standardized stimuli using other barium products (https://steeleswallowinglab.ca/srrl/).

There are five primary reasons to avoid off-label mixing of barium powders or suspensions with foods and liquids and instead implement a standardized protocol during the MBSS: (a) Aspiration of food and liquid materials may be a threat to pulmonary health in contrast to aspiration of inert barium; (b) alteration of contrast materials may not be compliant with food safety regulations, pharmaceutical regulations, and infection control policies at the examining institution; (c) mixing of standardized (factory produced, formulated, and premeasured with strict quality control monitoring) barium contrast agents with foods and liquids may alter their viability and visibility; (d) there is no guarantee that clinician-made mixtures in radiology will be replicated at the bedside; and (e) implementation of a standardized protocol that introduces barium contrast agents in graduated bolus volumes and consistencies minimizes risk associated with aspiration of large amounts of barium.

Clinicians who understand and are able to identify physiological elements of swallowing impairment in the context of multiple patient factors (cognition, adherence, support) are likely to predict how patients will swallow with very subtle changes to viscosity or with other modifications that impact bolus flow, such as adjustments of bolus size, patient position, and administration methods (Martin-Harris, Steele, & Peterson, 2020). Furthermore, because the MBSS provides a short sampling of swallowing function and patients' physical and cognitive status may vary throughout the day, findings should be validated, whenever possible, via direct or consultative observation of patient performance at the bedside or at mealtime. Diagnostic information attained from the MBSS, when paired with clinical observations, underlying diagnoses, and clinician judgment, provides the basis for determining and targeting patients' swallowing impairments.

Metrics for the Quantification of Type and Severity of Swallow Impairment

Multiple surrogate, visuoperceptual measures of skill and timing (Kendall et al., 2003, 2000; Martin-Harris et al., 2008, 2003, 2017, 2005; Molfenter & Steele, 2014), muscle contraction (Leonard et al., 2006, 2011), pressure generation (Cock & Omari, 2017; Omari et al., 2019; O'Rourke et al., 2017), airway protection (penetration/aspiration; Kahrilas et al., 1997; Robbins et al., 1999; Rosenbek et al., 1996), and efficiency (clearance of swallowed material; Hutcheson et al., 2017; Kahrilas et al., 1992; Martin-Harris et al., 2008, 2017; Pearson, Molfenter, et al., 2013) have been applied for quantification of swallowing impairment and interpretation of findings from videofluoroscopic images obtained during the MBSS. No one scale is perfect in measuring all aspects of multidimensional swallowing function, and several scales are often applied depending on the clinical or research question of interest. The limitations of psychometric properties of any measurement tool (Swan et al., 2019) must be balanced with the clinical validity of the tool items, reliability of measures, practicality of implementation, and feasibility for widespread dissemination and implementation.

Methods and measures used to study swallowing, particularly in a research setting, focus on specific research questions and include the temporal or coordinative aspects of the mechanism (Cook et al., 1989; Kendall et al., 2000; Martin-Harris et al., 2003, 2005), estimates of bolus clearance (Hutcheson et al., 2017; Kahrilas et al., 1992; Pearson, Molfenter, et al., 2013) and airway invasion (Hutcheson et al., 2017; Kahrilas et al., 1997; Robbins et al., 1999; Rosenbek et al., 1996), and degree of structural movements (Green & Wang, 2003; Logemann et al., 2000; Molfenter & Steele, 2014). More recent advances in imaging software have resulted in development of visuospatial measures (Garand et al., 2018; Pearson et al., 2016) and ratios of degree of movement relative to bolus flow (Allen et al., 2012; Leonard et al., 2006, 2011). Despite the utility and sophistication of these research approaches, there has not been widespread translation into clinical practice (Vose et al., 2018), in part because of the labor intensity of training required for application and interpretation. Future developments in operator-assisted machine learning approaches, however, may serve to further improve the accuracy, efficiency, reliability, validity, and feasibility of applying of these observational measures made from videofluoroscopic images in the context of clinical MBSS.

Primary Components of Swallowing Physiology

There is general consensus and evidence regarding the key elements that characterize swallowing physiology and components of impairment that warrant assessment on a standardized MBSS (ASHA, 2019; Logemann, 1983, 1998; Martin-Harris et al., 2008). These complex physiological elements generally fall within three functional domains, including the oral, pharyngeal, and esophageal domains (Cook et al., 1989; Dodds, Logemann, & Stewart, 1990; Dodds, Stewart, & Logemann, 1990; Logemann, 1998; Martin-Harris et al., 2008, 2017, 2005; Robbins et al., 1992). Functional domains differ from the traditional swallowing "phase" nomenclature, which is limited to characterization of bolus location (ingested material) in three distinct regions of the aerodigestive tract, and take into consideration the functional and temporal association of the components that affect a safe and efficient swallow. The physiological swallowing components of the functional domains are easily observed on videofluoroscopy when using sufficient, high-resolution acquisition and playback equipment by trained clinicians. Care should be taken to work with the radiologist, radiology assistant, radiology technician, and/or attending physician to achieve adequate framing of these desired anatomical structures. It is recommended that the patient be seated in a standardized chair (e.g., Hausted, TransMotion, and Steris for adults; MAMA Systems, Inc., for infants) or wheelchair offering stable support and visualization from mouth to stomach in the lateral and anterior–posterior (AP) planes, whenever possible. Able patients may also stand during the examination. The patient should remain in the upright position (90° standing or 70°–90° seated) for the duration of the study, unless positioning strategies are employed.

The primary components of swallowing physiology comprising the oral domain include lip closure or labial seal, tongue control and tongue-to-palatal seal to contain or hold a bolus with the oral cavity (Daniels et al., 2004; Dodds et al., 1989; Hiiemae & Palmer, 1999; Martin-Harris et al., 2008; Martin-Harris & Jones, 2008), mastication or bolus preparation (dependent on the bolus type), tongue movement to prepare and propel the bolus through the oral cavity (Green & Wang, 2003; Hannam et al., 2008; Hiiemae & Palmer, 1999; Kahrilas et al., 1993; Martin-Harris et al., 2008; Matsuo & Palmer, 2009; Pouderoux & Kahrilas, 1995; Storey, 1976), and initiation or triggering of the pharyngeal swallow in response to a multiplicity of sensory inputs (bolus characteristics, tongue movement, etc.) that stimulate sensory end organs in the oropharynx (Kendall & Leonard, 2001; Linden et al., 1989; Logemann et al., 2000; Martin-Harris et al., 2007; Rademaker et al., 1998; Robbins et al., 1992; Sonies et al., 1988; Yoshida, 1979).

The primary components of swallowing physiology comprising the pharyngeal domain include superior and anterior movement of the hyoid bone facilitating opening of the pharyngoesophageal segment composed mainly of the relaxed and compliant cricopharyngeal muscle with some contribution of the inferior constrictor muscle fibers (Asoh & Goyal, 1978; Cook et al., 1989; Jacob et al., 1989; Kahrilas et al., 1988; Martin-Harris & Jones, 2008; Miller et al., 2004; Miloro et al., 2014; Sivarao & Goyal, 2000); laryngeal elevation and pharyngeal shortening with consequent early closure of the laryngeal vestibule achieved by forwardly displaced arytenoid cartilages contacting a dynamic bulge in the epiglottic base (petiole) formed as the epiglottis descends to its first stage (horizontal) of movement (Dodds, Logemann, & Stewart, 1990; Dodds, Stewart, & Logemann, 1990; Ekberg & Sigurjónsson, 1982; Logemann et al., 1992; Martin-Harris et al., 2003; Martin-Harris & Jones, 2008; Molfenter & Steele, 2011; Pearson, Hindson, et al., 2013; Pearson et al., 2012; Vandaele et al., 1995); superior to inferior stripping motion of the pharyngeal constrictor muscles (Cerenko et al., 1989; Kahrilas et al., 1992; Martin-Harris et al., 2008; McConnel et al., 1988; Palmer et al., 2000; Sokol et al., 1966); retraction of the tongue base to contact the anterior and inward movement of the lateral and posterior pharyngeal walls (early part of the stripping motion; Logemann et al., 2000; Martin-Harris et al., 2008; Martin-Harris & Jones, 2008; McConnel, 1988; Pauloski & Logemann, 2000; Sokol et al., 1966); and complete closure of the laryngeal vestibule accomplished by maximum anterior movement of the hyolaryngeal complex, maximum retraction of the tongue base, and finally continuation of the pharyngeal stripping wave ending with final closure of the pharyngoesophageal segment (Logemann et al., 1992; Martin-Harris et al., 2008; Martin-Harris & Jones, 2008; Pearson et al., 2016).

When evaluating the esophageal domain, it is important to understand that neither the imaging protocol nor purpose of the MBSS is sufficient for complete assessment of esophageal function; rather, MBSS focuses on the degree and timing of esophageal bolus clearance (in the upright position) both of which influence oral and pharyngeal function (Gullung et al., 2012; Martin-Harris & Jones, 2008; Mendell & Logemann, 2002).

Intervention Planning and Reporting

The MBSS report should include quantitative, standardized measures of physiological swallowing impairment that are easily interpreted by any consumer (J. Jones, 2018; Martin-Harris et al., 2008, 2017); the presence, depth, and patient's response to penetration and aspiration (Rosenbek et al., 1996); and the effect of compensatory strategies. Recommendations should include food/liquid consistency tolerance and a management plan that may include swallowing rehabilitation using targeted, evidence-based interventions. It is important to note that empirical data are frequently lacking for many common interventions. Furthermore, when evidence is readily available, findings are not always generalizable to the heterogeneous patient populations encountered in clinical practice.

In 2012, an official multisociety statement was released by the American Thoracic Society, the American College of Chest Physicians, and the Society of Critical Care Medicine that guides clinical decision making in the context of evidence-based practice (Tonelli et al., 2012). Recommendations include consideration of (a) clinical research (evidence), (b) pathophysiological reasoning, and (c) clinical experience. Likewise, system constraints, patient preference, and underlying diagnosis should be considered when planning interventions. For example, some patient populations, such as those with progressive neurological disease, will require long-term use of compensatory strategies when a rehabilitation approach is not supported by empirical data or controlled studies.

Standardized assessment metrics included in the electronic medical record have had broad-based, clinical uptake facilitating big data registries that serve as platforms for discovery of highly relevant clinical issues such as identification of swallowing impairment phenotypes and dysphagia recovery patterns by disease and condition. Big data analyses of standard metrics reported by the SLP and the radiologist allow understanding of the natural history of swallowing decline in progressive diseases to expedite and enhance resource planning during management. Recommendations made by the SLP and the radiologist, either individually or jointly, should be consistent regarding general findings and impressions. Language used within the MBSS report should be standardized and interpretable by providers along the continuum of care.

Summary

The intent of the MBSS is to identify and distinguish the presence, type, and severity of physiological swallowing impairments; determine risk for compromising airway safety (penetration/aspiration) and swallowing efficiency (bolus clearance); test the immediate effects of online interventions; develop intake and nutritional management plans; and facilitate development of appropriate targeted, therapeutic interventions when possible. Valid and reproducible surrogate, visuoperceptual measures should be considered when quantifying swallowing impairment. Specific measures should be chosen depending on the clinical or research question of interest and capture the critical physiological elements that comprise the oral, pharyngeal, and esophageal domains of the swallowing mechanism. When these standard recommendations are followed, results from the MBSS are sufficient to document quantitative measures of physiological swallowing impairment; identify the presence, depth, and patient's response to penetration and aspiration; demonstrate the effect of compensatory strategies; and enable development of recommendations regarding oral intake and management plans that may include swallowing rehabilitation using targeted, evidence-based interventions.

From the Eyes of the Radiologist

Dr. Cheri Canon

The optimized performance of the MBSS is contingent upon many interrelated factors. Proper selection and use of fluoroscopic equipment by the radiologist are fundamental. The radiologist must also have an in-depth understanding of radiation dose and methods to optimize the study while reducing dose to both the patient and those participating. A detailed description of this has been previously published (Zarzour et al., 2018) and is further discussed below (see the Radiation and Cancer Risks From MBSS section). Before initiating the study, the radiologist and the SLP must consider the clinical indication for the examination and how it will affect the management of the patient. Factors impacting patient selection and timing of the exam have been previously well described (Brady & Donzelli, 2013; Langmore, 2006; Logemann, 1997). An MBSS should be introduced as soon as a patient presents with clinical signs and symptoms of dysphagia and the immediate clinical yield of the exam has potential to (a) change nutritional intake status, (b) change diet recommendations, (c) identify strategies to improve the patient's swallowing mechanics, (d) develop targeted interventions related to physiological impairment, and/or (e) prompt referral to another specialty for potential intervention (Logemann, 1997; Martin-Harris et al., 2000). If the MBSS will not impact patient care, then the need for its performance should be reconsidered. Performing the right exam, on the right patient, in the right location, and at the right time is best practice. This is the responsibility of both the radiologist and the SLP.

Role of the Radiologist During MBSS

Radiologists and SLPs implement a collaborative approach when conducting the MBSS. The radiologist consults with the SLP before the exam to review the patient's clinical history, during the exam to ensure the study is effective, and after the exam to coordinate their findings and review them with the patient. The radiologist assures the safety of not only the patient but also the SLP and others present in the fluoroscopy suite. The radiologist works in partnership with the SLP to determine appropriate patient positioning and constantly assesses risk to the patient. Unfortunately, MBSS are sometimes discontinued before completion because of airway invasion. In some cases, this may be a premature termination of the study as most patients referred for MBSS are at risk for penetration and aspiration, and the understanding of factors resulting in airway invasion is key for prescription of the most effective intervention. Radiologists must assess the volume of aspirate; the ability of the patient to clear their airway; and, importantly, the underlying condition and reserve of each patient. It is only with this entire complement of information that the radiologist can adequately evaluate the ongoing safety of the examination.

The complexity of the radiologist's role informs the Centers for Medicare & Medicaid Services (CMS) supervision requirements for the MBSS. These supervision levels can create confusion if not well understood and could result in inappropriate supervision and possible fraudulent billing. CMS defines three levels of supervision for hospital outpatient departments: (a) general, (b) direct, and (c) personal. General supervision requires the physician or advanced practitioner to be available by phone. Direct supervision requires the provider to be immediately available and interruptible. Personal supervision, which is required for MBSS, requires the physician or advanced practitioner to be present in the room for the entire examination. In order for the radiologist to be compliant with CMS billing for MBSS, they must be present in the room for the entire study. The radiology technologist does not qualify for this supervision requirement.

Interdisciplinary Standards Inform Patient Management

Ideal performance of the MBSS includes an agreed-upon protocol by the interdisciplinary team. This provides the most standardized and therefore reproducible evaluation, particularly important in assessment of patients over time. The Modified Barium Swallow Impairment Profile (MBSImP; Martin-Harris et al., 2008) is a tool that provides this standardization and continuity between the team members and across multiple studies and facilities. Use of a standardized protocol helps the radiologist know how to optimally conduct the exam. Structured reporting also provides reproducibility over time and reduces reporting variability. Collaborative teams provide the foundation for advancement of clinical knowledge and optimization of protocols.

Engagement between the radiologist and the SLP is critical, as they are often exposed to different bodies of scientific literature, and it is the cross-fertilization of this knowledge that allows for optimal practice. Without collaboration, lack of alignment may arise between team members. An example of a practice that can create interdisciplinary malalignment is the esophageal screening portion of the MBSS. This parameter is included as one of the data points in the MBSImP and assesses the clearance of a single bolus as it passes through the esophagus and the lower esophageal sphincter while the patient maintains an upright position. Literature shows that there is an association between oropharyngeal and esophageal motility (Gullung et al., 2012). An abnormal esophageal screen (i.e., delayed clearance) indicates additional evaluation is warranted and may include manometry or biphasic esophagram if the patient is able to safely tolerate these procedures (Allen et al., 2012; Gullung et al., 2012). Swallowing involves complex physiology, and oropharyngeal and esophageal motility are inextricably linked (Triadafilopoulos et al., 1992). Separating the MBSS from fluoroscopic evaluation of esophageal motility is an artificial construct driven by protocol; coding; and, in some cases, reimbursement. The patient and their symptoms should be the primary driver of study performance. This quick evaluation may provide significant clinical data with a miniscule increase in radiation dose. Radiologists may be concerned that the examination is not complete; however, a brief description of the limited review of contrast clearance in the report should address these concerns.

Barriers to Collaboration

The interdisciplinary collaboration between the radiologist and the SLP assures the best care for the patient. Unfortunately, this approach has not been embraced in some practices. This is particularly concerning as the number of MBSS studies will likely increase with our aging patient population and improved survival of infants with medically complex conditions. One of the greatest challenges faced by SLPs is lack of a radiologist partner. In the current health care environment, radiologists and radiology practices are under increased demands. For most practices, there has been tremendous growth in the number of imaging studies, and in many cases, the complexity of patients and their diseases has also increased while there may not be a commensurate increase in radiologist staffing. Patient throughput, length of stay, and patient discharges are under constant scrutiny, along with radiologists' turnaround time and productivity data.

Studies such as MBSS may suffer as they are viewed as time consuming with relatively low work relative value units (wRVU) used to measure productivity. Unfortunately, some practices have developed a culture that prioritizes radiologists remaining in the reading rooms and interpreting those studies with higher wRVU values. This situation is further complicated because of the decline in fluoroscopy training during residency, particularly MBSS. Many residency programs do not have a champion to teach this important and complicated study. This does not assure the most up-to-date understanding of the literature and scientific advances. Opportunities to demonstrate the importance of understanding the complexities of pharyngeal swallowing and how to run a fluoroscopy practice may be squandered. However, collaboration can be fostered by relatively simple and non–time-consuming activities, such as literature review and protocol development. The radiologist and the SLP should confer before entering the fluoroscopy suite and ideally interview the patient together, although the latter may not always be possible. Ideally, interdisciplinary conferences prove the best opportunity for a team approach, particularly for complex patients.

Summary

Enhanced performance of a collaborative MBSS is contingent upon proper selection and use of the fluoroscopic equipment by the radiologist, an in-depth understanding of radiation dose and methods to reduce exposure while optimizing the study, and an agreed-upon protocol by the interdisciplinary team. It is the responsibility of both the radiologist and the SLP to consider the clinical indication for the examination and how it will affect the management of the patient. If the MBSS will not impact patient care, then the need for its performance should be reconsidered. Personal supervision, which is required for MBSS, requires the physician (radiologist) or an advanced practitioner to be present in the room for the entire examination. As such, the radiologist assumes responsibility for the safety of the patient, the SLP, and others present in the fluoroscopy suite. Collaboration between the radiologist and the SLP assures best care for the patient as both are exposed to different bodies of scientific literature that contribute to optimal practice. Opportunities to demonstrate the importance of understanding the complexities of pharyngeal swallowing and how to run a fluoroscopy practice are aided by this type of engagement between the radiologist and the SLP.

Technical Parameters for Recording and Reviewing the MBSS

Dr. Joseph Murray

Accurately perceiving an abnormality during a radiological examination is vital for effective diagnosis and has been an area of clinical interest since the development of modern medicine in the mid-20th century (Garland, 1949, 1959). Once perceived during the "detection phase," an abnormality needs to be integrated into a clinician's "cognitive set" of rules during the "interpretation phase." It is suggested that errors often occur during the viewing stage of the diagnostic examination (Bruno et al., 2015; Renfrew et al., 1992; Scaglione, 2015), and Pitman (2006) proposed that an error that occurs at the detection phase is, almost without exception, a perceptual error.

During the oropharyngeal swallow, discrete events, with durations of milliseconds, may reveal the presence or absence of an abnormality that is crucial to the accurate and reliable interpretation of the MBSS. Guidelines written for the administration of the exam suggest that practitioners review recordings following a procedure and further propose that the review allows for slow motion and frame-by-frame analysis (ASHA, 2004; Levine et al., 2009; Logemann, 1983). In spite of this, the accuracy of interpretation can be corrupted when there is inadequate equipment for viewing and recording the examination during the initial live study or during playback of an archived examination. Furthermore, clinical practice patterns for administration, recording, and reviewing of the MBSS vary widely (Martin-Harris, 2007).

Image Acquisition Practices and Standards

Image capture, archival, and retrieval can be corrupted and distorted at many points in the administration of the examination. The quality of the imaging may be affected by a number of factors, which may include variation in the concentration of nonstandardized barium preparations as well as the brightness, contrast, and density of the originating image. Even if captured correctly, many of these elements can be corrupted during the transfer of the captured image to a storage device and the forwarding of the stored image to a picture archiving and communication system that is viewed by the end user at a location remote to the radiology suite (Peladeau-Pigeon & Steele, 2015). If not carefully configured, these additional steps may further degrade the image that is received with resulting decrements in detection and associated distortions in the integration of the image into the clinician's diagnostic algorithm. These errors can lead to misdiagnosis, imperiling the patient's health and quality of life as well as incurring additional costs in the delivery of care.

In an attempt to reduce error, considerable attention has been directed to improving live fluoroscopy display with resulting improvement in pixel density, brightness, and contrast of the radiological imaging (Seeram et al., 2014). While improvement in these components is important, there is still concern regarding the temporal resolution (fluoroscopic pulse rate) of the continuous image that is acquired during a dynamic MBSS. In modern digital fluoroscopy, the temporal resolution of image capture can generally range from 2 to 30 pulses per second (PPS). Lower pulse rates have been advocated to reduce radiation exposure during diagnostic exams (see the Radiation and Cancer Risks From MBSS section; Hernanz-Schulman et al., 2011); however, recent studies have indicated that the use of lower pulse rates results in diagnostic inaccuracy (Bonilha, Blair, et al., 2013; Cohen, 2009). Intuitively, a lower pulse rate would not provide imaging of very rapidly evolving physiological movements, such as thin liquid bolus advancement, sequential pharyngeal contractions, or airway closure. It has been suggested that some discernments (i.e., measures of delayed swallowing) require the clinician to determine normality or disorder based on differences of very short durations, sometimes as short as one tenth of a second (Clavé et al., 2006). Given this, there is concern that a loss of any frame could lead to misdiagnosis.

In a study by Bonilha, Blair, et al. (2013), clinicians viewed studies at the maximum temporal resolution of 30 PPS and at a lesser resolution of 15 PPS while employing a standardized scoring method (MBSImP and Penetration–Aspiration Scale). The clinicians viewing the studies were also asked to make treatment recommendations following both viewing conditions. The authors found significant differences in both physiological observations and in the detection of penetration and aspiration when comparing the two pulse rate recordings. Perhaps most remarkably, the authors noted a difference in recommendations for treatment when pulse rates were reduced. As previously discussed, misdiagnosis can imperil the patient's health and quality of life. In a similar study, Mulheren et al. (2019) also found differences in certain duration and functional measures of swallowing when comparing 15 PPS to 30 PPS. These findings would suggest that the best practice for capturing and reviewing the MBSS should require image acquisition at 30 PPS as there is a demonstrable reduction in perceptual error.

Methods for Reviewing Radiographic Images

Even when given identical sets of images, there may not be a uniform detection of abnormalities among clinicians. In an early study of search patterns, it was determined that more experienced radiologists actually scan radiographs differently and more efficiently than novices (Kundel & Wright, 1969). Studies using eye-tracking software have shown that more experienced radiologists have different gaze patterns and dwell times when compared to those with less experience (Kundel et al., 2007). It has been suggested that employment of slow motion review also enhances an individual's ability to perceive the presence of an abnormality (Murray et al., 2007). In this study, groups of SLPs that performed a large volume of MBSS in their clinical practice were compared with clinicians that performed fewer examinations. The groups were asked to view MBSS in both real-time playback and slow motion playback. Unsurprisingly, those performing more exams were found to perform better than the low frequency of practice group under both viewing conditions. One might speculate that a real-time playback testing condition may favor the clinician with heightened visual processing skills, while slow motion playback would enhance the detection of abnormalities. This proved to be the case as the less practiced group performed significantly better during the slow motion playback condition. It was proposed that modification in the speed of the visual review allowed the individual to more readily receive the visual information, detect an abnormality, and then refer to their knowledge base regarding swallowing function during the interpretation phase.

It has been suggested that higher frequency of performance of any diagnostic test results in a "practice" effect, which gives individuals a heightened awareness of abnormal signs during real-time review and, perhaps, a larger and more rapidly accessible knowledge base of abnormalities that they can draw from to compare the study they are viewing to those they have witnessed in the past. It is possible that there is a "holistic" perception in those with a high frequency of practice that enhances quick identification of abnormalities during real-time review and facilitates a quick, true-positive identification of abnormalities. Use of slow motion and frame-by-frame review enhances accuracy of MBSS interpretation and should be considered a best practice.

Summary

Clinicians performing the MBSS should be aware of several factors that may affect both the detection and interpretation phases of the exam. They should strive to optimize the fluoroscopic image from initial image capture to storage and then to retrieval to assure that image integrity is maintained throughout. They should also employ a best practice of ensuring that the temporal density of the captured image is maximized to 30 PPS and that slow motion and frame-by-frame review be utilized to enhance accuracy of MBSS interpretation.

Radiation and Cancer Risks From MBSS

Dr. Heather Bonilha

MBSSs, like other radiography studies, expose patients to ionizing radiation. Radiation is the transmission of energy through electrons or electromagnetic waves made of photons. X-rays are one type of electromagnetic waves (Bushberg et al., 2012). The photons that make up X-rays have so much energy that they can remove bound electrons causing ionization (Bushberg et al., 2012). Ionization is what we worry about as it breaks molecules apart and can alter their function or cause them to abnormally reproduce.

Radiation dose can be measured in several ways, each with a very specific meaning. In the literature, typically, values are reported for absorbed dose and effective dose. Absorbed dose is a measurement attainable from the fluoroscopy unit that specifies the amount of radiation for a given exam (Bushberg et al., 2012). Effective dose is calculated and accounts for the relative amount of energy absorbed by each organ, the type of radiation deposited, and the radiosensitivity of each organ (Bushberg et al., 2012). Calculations of effective dose account for many patient and fluoroscopy unit characteristics. Effective dose can further be used to estimate cancer risk when accounting for additional patient characteristics.

Radiation Dose

While any medical use of radiation deserves serious oversight, it is incredibly important to consider the degree of risk associated with MBSSs in the context of other sources of radiation in daily life and medicine. Data from the National Council on Radiation Protection and Measurements on population radiation exposure demonstrate that radiation exposure from conventional radiography/fluoroscopy (the category that includes MBSSs) makes up only 5% of the average U.S. radiation dose. The U.S. Nuclear Regulatory Commission's website (https://www.nrc.gov/about-nrc/radiation.html) is a good resource for learning more about sources and amounts of radiation exposure in daily life. This is also a great resource for concerned patients to help put the radiation exposure from MBSSs in context.

Recent experiments on radiation exposure to adults undergoing MBSSs found the average exposure to be 0.27 mSv per MBSS (for perspective, this is less than the amount of radiation emitted from a person's body in a year and similar to the radiation exposure associated with living 32 days on earth; Bonilha, Huda, et al., 2019). This radiation exposure is less than that from a mammogram (0.4 mSv) and approximately one eighth that from a head computed tomography (2 mSv; Bonilha, Huda, et al., 2019). This puts MBSSs of adults into the low radiation exposure range.

There is variation in the radiation exposure data reported in the literature for adults undergoing MBSSs. This variation comes from several factors that are important to consider and include (a) the duration of the examination, (b) the use of a standardized protocol, (c) the methodology used to calculate exposure, (d) the position of the patient, and (e) the parameters of the fluoroscopy unit. (a) If all else is constant, a longer examination will result in increased exposure. However, given that patient and exam characteristics vary, the dose area product is a better indicator of exposure because it is a measure of radiation emitted from the fluoroscopy unit (Bonilha, Wilmskoetter, et al., 2019). (b) In contrast, experienced clinicians who target the MBSS to specific clinical concerns and those who use a standardized method for conducting an MBSS are likely to minimize time and therefore radiation exposure, compared to those who do not use a protocol (Bonilha, Humphries, et al., 2013). (c) The methodology used to calculate exposure, contributes to variation. Some studies use data from general gastroenterology system models to calculate effective dose instead of modeling the exam characteristics related to the data collected/being analyzed. While this method provides some approximation, the MBSS is unique to other gastrointestinal-focused uses of radiation, specifically in regard to thyroid exposure and, therefore, is less accurate than using an MBSS-specific model. (d) Patient positioning during the MBSS can also impact radiation exposure as some organs are more radiosensitive than others. In MBSS, the main radiosensitive organs are the thyroid and lungs (during evaluation of esophageal clearance; Bonilha et al., 2018). Furthermore, body mass influences the radiation exposure. More radiation exposure is needed to create an image for greater masses. Thus, if all else is similar, MBSS conducted in the lateral position are associated with less radiation exposure than those conducted in both lateral and AP positions (Bonilha, Wilmskoetter, et al., 2019). However, the diagnostic information gained from the AP view has been shown to be valuable for clinical decision making for adult patients undergoing MBSSs (Hazelwood et al., 2017). Given that overall radiation exposure is very low for an adult MBSS, the AP view should not be removed from the exam due to radiation exposure concerns. (e) Finally, the parameters of the fluoroscopy unit including the use of magnification, collimation, filtration, X-ray beam quality (kV and mA), and continuous versus pulsed mode can result in variations in radiation exposure (Mahesh, 2001). It is important to consider these sources of variation when reading the literature and when assessing radiation exposure specific to a fluoroscopy unit in one's hospital.

The age of the patient adds variation to radiation exposure data. Infants and young children are considerably smaller than adults and, therefore, have less mass that needs to be penetrated by the fluoroscopy beam to capture signals. In general, this means that radiation exposure to children is less than that to adults. However, the fluoroscopy unit setup may need to be different to accommodate the image quality and spatial resolution requirements for acquiring clinically important information in young children. For example, infants and young children have more soft tissue versus ossified cartilage and therefore may require a different beam quality and/or filtration to allow for sufficient image contrast. Furthermore, the size of the structures that are being imaged in young children is smaller and often requires magnification, with increased radiation exposure (Mahesh, 2001).

Cancer Risk

Cancer risk is the main concern with MBSS as the radiation levels are much too low to cause deterministic effects (Bonilha, Huda, et al., 2019; Bushberg et al., 2012). Deterministic effects only occur at very high levels of radiation exposure and include radiation sickness, skin burns, and eye cataracts (Bushberg et al., 2012). However, since there is no minimum threshold for stochastic effects (such as cancer risks or genetic changes related to hereditary defects), any examination using ionizing radiation (no matter how small the amount) must consider these risks. When determining cancer risks from low levels of ionizing radiation, organ exposure, age, and sex are considered. Based on our results, the level of radiation exposure from adults undergoing MBSS has a related cancer incidence risk ranging from 0.0032% for a 20-year-old woman to 0.00049% for a 60-year-old man (Bonilha, Huda, et al., 2019). In comparison, conservative U.S. cancer incidence data estimate that 38% of the population will have a diagnosis of cancer in their lifetime (American Cancer Society, 2019). These values indicate an extremely low increased cancer incidence risk of less than 0.0097% for a 20-year-old woman with lower increased risks for men or older individuals (Bonilha, Huda, et al., 2019).

Regardless of the low levels of exposure, due to the lack of a minimum threshold for stochastic effects, we must comply with guidelines for the safe use of ionizing radiation. One such guideline is ALARA (or As Low As Reasonably Achievable; Baert, 2008; Tolbert et al., 1996). This concept assures that radiation exposure is considered in every patient care decision and that it is minimized while maintaining a diagnostic study. Please note that it is the clinician's responsibility to determine what is reasonably achievable. This is important to consider as the intent of ALARA is not to sacrifice patient care or a necessary level of diagnostic accuracy in order to lower radiation exposure. If a clinician has made the decision to expose a patient to radiation to attain medically important information, then it is the clinician's responsibility to get that information and not sacrifice it for the relatively small amount of additional radiation exposure associated with completing a thorough, clinically indicated exam. Given the low risk of cancer for adults undergoing MBSS, clinicians should repeat the exam whenever information is needed to make clinical decisions.

As with radiation exposure, age is also a critical factor that one considers when calculating the associated cancer risk from MBSS. Cancer risks are much higher for babies than older adults for two main reasons: (a) Developing cells are more sensitive to radiation exposure and (b) children have a longer life expectancy and therefore an increased likelihood for effects of radiation exposure to develop into cancer (K. J. Strauss, 2007; Tolbert et al., 1996; Weir et al., 2007). More specifically, cancer risks associated with radiation to the thyroid, the main radiosensitive organ irradiated in MBSS (Bonilha et al., 2018), are exponentially higher in children, especially female children, than adults. In the seventh publication from a series of reports on the Biological Effects of Ionizing Radiation (BEIR VII) female infants have a cancer risk of 634 per 100,000 exposed to 100 mGy of X-rays versus 115 for male infants and four for 50-year-old women (National Research Council of the National Academies, 2005). Research to determine the cancer risks to children undergoing MBSSs, in experiments that mirror the work with the adult patient population, is ongoing.

Radiation Monitoring and Protection

The radiologist can serve an important educational role by providing accurate information concerning potential occupational exposure for SLPs (Hayes et al., 2009). Although exposure during MBSS is relatively low dose, the exam involves ionizing radiation, and clinicians may participate in numerous studies on a daily basis. Many fluoroscopy machines have high-, normal-, and low-dose settings. The radiologist must be familiar with the default setting for this and other aspects of the fluoroscopy unit that may impact radiation exposure (magnification, filtration, etc.). Appropriate protective lead aprons and thyroid shields should be worn at all times during fluoroscopy. Measures such as positioning relative to the patient and avoiding placement of hand or arm directly in the fluoroscopy beam can further reduce exposure. Simply taking one step away from the patient can significantly reduce the exposure to providers. The inverse square law states that doubling the distance from the X-ray tube reduces the radiation intensity by fourfold (Mahesh, 2001). Dosimeter badges are to be worn during all studies and should be positioned at the collar level on the outside of the lead apron.

There can be additional concerns by the pregnant SLP. Continuing usual work activities can be completely safe for the mother and unborn child as long as certain precautions are taken. Many radiologists and SLPs safely continue their fluoroscopy practices through the entire pregnancy (Vu & Elder, 2013). Informing the hospital's radiation safety committee or radiation safety officer will allow for the appropriate exchange of information, and an additional radiation badge can be issued. It should be worn over the abdomen under the lead apron to assure no exposure to the developing fetus. Women may choose to wear a special pregnancy lead apron, which provides more comfort in the late stages of pregnancy. A second lead skirt can also be worn under the standard apron. Although a safe environment, ultimately, it is the mother's decision whether to continue her routine MBSS practice during her pregnancy (International Commission on Radiological Protection, 2000).

Summary

Current evidence on radiation exposure and cancer risks confirms that the MBSS is a low-dose exam. The cancer risks for adults undergoing MBSS are very low and should not drive clinical decision making (use of pulse rates of 15 PPS or lower, deciding not to do an MBSS because of radiation exposure concerns, limiting the time of the MBSS due to radiation concerns at the cost of acquiring clinically important information). Similar cancer risk information for infants and children is a focus of current research and will guide future clinical care decisions. For adults or children undergoing MBSS, using pulse rates of 15 PPS has been shown to decrease diagnostic accuracy and impact treatment decision making. Best practice is to use a pulse rate of 30 PPS. Despite the low levels of radiation exposure and cancer risks, MBSS should only be conducted when it is expected to provide clinically important information. Protective measures such as wearing appropriate lead aprons and thyroid shields, positioning relative to the patient, avoiding placement of hand or arm directly in the fluoroscopy beam, and monitoring exposure via proper use of a dosimetry badge can reduce exposure to providers.

Decisions About VFSS in Infants and Young Children

Dr. Maureen A. Lefton-Greif

The incidence of pediatric dysphagia is increasing (Horton et al., 2018). This rise is attributed to a combination of the improved survival of children with complex medical and health conditions and the longer life expectancies of children affected with conditions (e.g., cerebral palsy) associated with dysphagia (D'Amore et al., 2011; Glass et al., 2015; Patel et al., 2017; Serenius et al., 2013; Speyer et al., 2019; D. Strauss et al., 2007; Younge et al., 2017). These population trends have prompted questions about the early detection of swallowing problems and prompt interventions to reduce the dysphagia-induced comorbidities, including respiratory and nutritional compromise, the development of chronic feeding problems, and stressful child and caregiver interactions. As a result, VFSS/MBSS is more frequently performed in children of all ages. The terms VFSS and MBSS refer to the same exam, with the term VFSS more commonly used in children.

Clinical Utility and Standardization of the VFSS Procedure

Logemann (1983) described VFSS examinations as being designed to assess not only "whether" the patient is aspirating but also the "reason" for the aspiration so appropriate treatment can be initiated. Adherence to these two purposes for VFSS examinations has remained the same for the past three decades (Arvedson & Lefton-Greif, 2017). As with many aspects of health care, some degree of variation is unavoidable, and tailoring the examination to the needs of the specific child may be in the child's best interest (Arvedson & Lefton-Greif, 1998; Hiorns & Ryan, 2006; Jacobs & Duncan, 2009). Therefore, clinicians are urged to make decisions about the potential diagnostic and therapeutic utility of a VFSS while balancing the factors unique to the individual child with components of the examination that can be controlled. Careful decision making is essential when considering the clinical utility of procedures associated with exposure to ionizing radiation for all patients and particularly with infants and young children (see the Radiation and Cancer Risks From MBSS section). This decision making is confounded by the variability in how procedures are conducted and interpreted (Henderson et al., 2016; Hiorns & Ryan, 2006; Lefton-Greif et al., 2018; Nordin et al., 2017).

The absence of standardization and its subsequent adverse impact are well recognized in nonmedical fields (e.g., automotive and aerospace) and have resulted in the implementation of uniform procedures (Jacobs & Duncan, 2009). Variability in health care is rampant. Importantly, excessive and unnecessary variability has been implicated in higher health care costs, more frequent hospitalizations, and the proliferation of diagnostic imaging (Florin et al., 2013; Knapp et al., 2013; Neuman & Chiang, 2013; Tieder et al., 2013). Standardization of VFSS examinations in infants and young children is in its "infancy." In the future, procedural uniformity, to whatever extent possible, may decrease radiation exposure, facilitate the exchange of information derived from studies, and provide quantifiable targets for interventions (Lefton-Greif et al., 2018). At the time of this writing, evidence-based guidelines for standardizing VFSS procedures in infants and young children are lacking (Henderson et al., 2016; Hiorns & Ryan, 2006; Lefton-Greif et al., 2018; Thompson et al., 2018).

Regardless of age, VFSS examinations should be completed only for infants or children (a) with documented or suspected oropharyngeal swallowing impairments; (b) who demonstrate the medical stability, ability, and readiness to participate in the procedure; and (c) with anticipated findings that will impact management plans (Arvedson & Lefton-Greif, 1998, 2017). The same considerations are used for decisions about repeating VFSS examinations. Changes in status or the need for "new" information dictates the need for repeat examinations and not arbitrary time intervals (Arvedson & Lefton-Greif, 1998, 2017).

Potential Sources of Unnecessary Variability During the VFSS Procedure

The skills of the examining clinician and institutional wisdom are two potential sources of variability that may be amenable to modification. In comparison to trained clinicians, novices are more likely to recommend instrumental evaluations and are more likely to have longer fluoroscopy times (associated with higher levels of radiation exposure; Bonilha, Humphries, et al., 2013; Mathers-Schmidt & Kurlinski, 2003). The ability to target interventions based on physiological impairments rather than bolus flow is dependent upon training (Slovarp et al., 2018). Importantly, training with VFSS examinations for adults does not translate into adequate training for identifying physiological impairments in infants and young children; however, reliable training for the identification of these aberrant physiological components of swallowing can be achieved regardless of previous experience (Lefton-Greif et al., 2018).

Modification of institutional protocols to achieve standardized examinations is possible when radiologists and SLPs collaborate. Specifically, the field of view (FOV), magnification, and image acquisition rate can be standardized to limit radiation exposure in infants and children without sacrificing image quality (Lefton-Greif et al., 2018; Thompson et al., 2018). Standardization of magnification to visualize the space between laryngeal surface or the epiglottis and arytenoids is approximately 6.7 FOV (Martin-Harris, Carson, et al., 2020). FOV is defined as the maximum diameter of the area imaged. A smaller FOV is associated with greater magnification. In a quality improvement study, recommendations were to not exceed 2× magnification in patients younger than 1 year of age or 1× magnification in those older than 1 year of age (Thompson et al., 2018). Use of standardized barium sulfate contrast agents is needed to compare results from repeated studies for individual children and across specific diagnostic populations.

Another area of controllable variability is the pulse rate for image acquisition. As previously discussed, the standard of care for adults has been continuous fluoroscopy or 30 unique PPS (Bonilha, Blair, et al., 2013; Logemann, 1998; Martin-Harris & Jones, 2008; Peladeau-Pigeon & Steele, 2015). One study of patients (ranging from 9 days to 21 years), with imaging restricted by equipment to 25 PPS, reported the identification of structures with radiation screening times and dose area products within the previously reported ranges for pediatric VFSS studies (Henderson et al., 2016; Weir et al., 2007). Pulse rates of less than 30 PPS for children have been advocated to reduce exposure during evaluations. However, there are concerns about missing episodes of supraglottic penetration or aspiration during VFSS examination in babies and young children with lower frame rates (e.g., 12.5–15 PPS; Cohen, 2009). With lower pulse rates, it is not known whether examinations are longer or are repeated more often because important findings may have been missed. In adults, lower pulse rates have been associated with compromises in clinical utility (Bonilha, Blair, et al., 2013).

Standardization of the type and severity of swallowing impairments from fluoroscopic images during adult swallow studies has been achieved (Martin-Harris et al., 2008). A comparable tool has been developed and tested (Lefton-Greif et al., 2018; Martin-Harris, Carson, et al., 2020) for the objective quantification of physiological swallowing impairments during bottle feeding in babies. Widespread clinical implementation of objective VFSS measures will help achieve these goals (Martin-Harris, Carson, et al., 2020; Nordin et al., 2017).

Summary

Across the age span, the VFSS assesses not only "whether" an aspiration is occurring but also the "reason" for the aspiration. Clinicians should make decisions about the potential diagnostic yield of the exam while taking into consideration factors unique to the individual child. While a standardized tool for bottle-fed children has been developed and tested (Lefton-Greif et al., 2018; Martin-Harris, Carson, et al., 2020) for the objective quantification of physiological swallowing impairments, decision making during the procedure is confounded by lack of standardization of the VFSS protocol. Current best practices dictate that VFSS examinations should be considered for infants and young children with documented/suspected oropharyngeal dysphagia, who are medically stable and able to participate, and when findings are anticipated to impact management plans (Arvedson & Lefton-Greif, 1998).

Conclusions

While MBSS are important exams for the care of patients with swallowing impairments, they must be conducted according to best practices to provide accurate information regarding patient function to direct treatment planning. A summary statement is provided at the end of each section throughout this review article to aid rapid translation of the presented content. The standards and issues discussed, in combination with the referenced publications, provide a basis for understanding the best practices for MBSS.

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