Published in final edited form as:
Dysphagia. 2013 March ; 28(1): 77–85. doi:10.1007/s00455-012-9415-z.

Radiation Exposure Time during MBSS: Influence of Swallowing Impairment Severity, Medical Diagnosis, Clinician Experience, and Standardized Protocol Use

Heather Shaw Bonilha, PhD, CCC-SLP[1,2], **Kate Humphries, MSP, CF-SLP**[3], **Julie Blair, MA, CCC-SLP**[3], **Elizabeth G Hill, PhD**[4], **Katlyn McGrattan, MSP, CF-SLP**[1,3], **Brittni Carnes, MSP, CCC-SLP**[3], **Walter Huda, Ph.D.**[5], and **Bonnie Martin-Harris, PhD, CCC-SLP**[1,2,3]

[1]Department of Health Sciences and Research, Medical University of South Carolina, Charleston, SC

[2]Department of Otolaryngology – Head and Neck Surgery, Medical University of South Carolina, Charleston, SC

[3]Evelyn Trammell Institute of Voice and Swallowing, Medical University of South Carolina, Charleston, SC

[4]Biostatistics and Epidemiology, Medical University of South Carolina, Charleston, SC

[5]Department of Radiology, Medical University of South Carolina, Charleston, SC

Abstract

Purpose—Guidelines and preventive measures have been established to limit radiation exposure time during modified barium swallow studies (MBSS) but multiple variables may influence exam duration. This study examines the influence of clinician experience, medical diagnosis category, swallowing impairment severity and use of a standardized protocol on fluoroscopy time.

Methods—A retrospective review was completed on 739 MBSSs performed on 612 patients (342 males/270 females; age range = 18 to 96 years) completed in one year at the Medical University of South Carolina with IRB approval. All studies were completed by speech-language pathologists trained in the data collection protocol, interpretation, and scoring of the MBSImP™©. Medical diagnosis category, swallowing impairment severity (MBSImP™© score), clinician experience, and fluoroscopy time were the variables recorded for analysis.

Results—Fluoroscopy time was not significantly associated with medical diagnosis category ($p=0.10$). The severity of the MBSImP©™ Oral Total and Pharyngeal Total resulted in statistically significant increases in fluoroscopy time ($p<0.05$). Studies by novice clinicians had longer exposure times when compared to experienced clinicians ($p=0.037$). Average radiation exposure time using the MBSImP©™ approach was 2.9 minutes, with a 95% confidence interval of 2.8 minutes to 3.0 minutes, which was well within the range of exposure times reported in the literature.

Conclusions—This study provides preliminary information regarding the impact of medical diagnosis category, swallowing impairment severity and clinician experience on fluoroscopy time. These findings also suggest that a thorough, standardized protocol for MBSSs did not cause unnecessary radiation exposure time during the MBSS.

Address for Correspondence: Heather Shaw Bonilha, PhD, CCC-SLP, Department of Health Science and Research, Medical University of South Carolina, 77 President St, Charleston, SC 29425, Tel: (843) 792-2527, Fax: 843-792-1358, bonilhah@musc.edu.

Keywords

Deglutition; Swallowing; Dysphagia; Modified Barium Swallow Study; MBSImP©™; Fluoroscopy; Radiation; Radiation Exposure

INTRODUCTION

Swallowing impairment (dysphagia), a comorbidity of many medical conditions and diseases, is associated with increased morbidity and mortality, and negatively affects patient quality of life [1,2]. The prevalence of dysphagia is estimated to be up to 22% in persons 50 years and older [3] with 10 million Americans evaluated for swallowing dysfunction each year [4]. Oropharyngeal swallowing impairment is assessed using a videofluoroscopic approach during a modified barium swallow study (MBSS). The MBSS permits the visualization of bolus flow in relation to structural movement throughout the upper aerodigestive tract in real time. The MBSS also permits detection of the presence and timing of aspiration, i.e., entry of ingested material below the level of the true vocal folds into the trachea, and assists in identifying the physiologic and often treatable cause(s) of the aspiration [5–8]. Furthermore, MBSSs allow clinicians to observe the effects of various bolus volumes, bolus textures, and compensatory strategies on swallowing physiology [9]. While the information gained from MBSSs is critical to patient management, it is a fluoroscopic procedure and as such involves radiation exposure.

Relationship between Radiation Exposure and Fluoroscopy Time

Although the patient radiation dose from a MBSS is relatively low, between 0.2 and 0.85mSv [10–17], any radiation from medical tests must be minimized to comply with the As Low As Reasonably Achievable (ALARA) principle [18]. The total radiation exposure time is one of the most important factors influencing patient doses in fluoroscopy examinations [19]. In MBSSs, fluoroscopy time has been shown to be highly correlated with kerma area product (KAP) values and is recognized as a practical tool for monitoring patient radiation dose for units that lack KAP meters [20]. However, it is important to note that although fluoroscopy times can serve as a *relative* indicator of patient exposure, this parameter has major limitations when comparing procedures performed on different types of equipment, and at diverse facilities. Patient dose depends on both the x-ray beam quantity (KAP) and quality (Half Value Layer) incident on the patient.

Furthermore, both the irradiation geometry and patient physical characteristics should be accounted for. Fluoroscopy times during MBSSs have been reported in numerous studies. In a review of the literature, we identified 11 peer-reviewed manuscripts that reported fluoroscopy times or fluoroscopy time guidelines for MBSSs. [10–17, 21–23] The literature reports radiation exposure times for MBSSs ranging from 150 seconds (sec) to 1080 sec. These studies show that factors influencing radiation exposure time in MBSSs include: medical diagnosis category, swallowing impairment severity, clinician experience, and use of a standardized protocol.

Swallowing Impairment Severity

According to anecdotal reports, swallowing impairment severity influences radiation exposure time. Interestingly, these reports present conflicting viewpoints on the direction of influence of swallowing impairment severity. For example, some clinicians report anecdotally that less severe patients may have faster examinations since they are able to quickly proceed through the protocol with fewer repeat swallows and compensatory techniques. Other clinicians report that severe patients may actually have faster examinations because they may demonstrate aspiration on initial swallows and the examination would be terminated prior to the introduction of additional bolus volumes and consistencies. Further, dysphagic patients with moderate swallowing impairment severity may have longer fluoroscopy times because of trial and error attempts to optimize the compensatory effects of bolus variables and strategies. While there is no published research on the impact of swallowing impairment severity on fluoroscopy times during MBSSs, these anecdotal reports are the basis for hypothesizing a fluoroscopy time distribution where patients with swallowing impairment severity at the extremes (mild and severe) have lower fluoroscopy times than patients with moderate impairments.

Medical Diagnosis Category

There is a perception that complex medical conditions may result in more complex swallowing impairment and hence require more time to complete the examination. Examples of such medically complex conditions include: neurologic disorders that influence the patient's cognitive function, sustained upright positioning, or surgical ablation in cancer. These clinical variables may require cuing for patient participation and multiple positioning attempts to fully visualize the desired imaging field leading to extended fluoroscopy times. Without the benefit of previously published research on the relationship between medical diagnosis category and fluoroscopy time, we suspected that patients with diagnosis known to have complex swallowing impairments such as, head and neck cancer, and neurologic related diagnoses would have longer fluoroscopy times than patients with pulmonary or cardiac-related diagnoses.

Clinician Experience

It is widely believed that less experienced clinicians take longer to complete MBSSs. Three reasons for this may be difficulty interpreting swallow impairment in real-time, trial of more treatment and compensatory strategies because they don't have the level of clinical experience to narrow the strategy options, and ability to manage difficult-to-study patients. Studies on fluoroscopy time during procedures other than MBSS support this belief.[24] There are no studies investigating the impact of clinician experience on fluoroscopy time in MBSSs. Given findings of the influence of novice clinician experience on longer fluoroscopy time in other procedures, we expect to find similar influence in fluoroscopy times of MBSSs

Standardized Protocol

Standardized protocols, because they are thorough and include the administration of several bolus types and trials, have the potential for lengthening fluoroscopy exposure time. The clinical yield of a standardized protocol for the performance of MBSSs is expected to be higher than the yield without standardization. The benefit of the increased yield would need to exceed the risk of the additional radiation exposure if a standardized protocol is found to be associated with longer fluoroscopy time. The use of a standardized data collection protocol provides an evidence-based guide to the types and amounts of boluses presented during the MBSS. This ensures that the MBSS is thorough and is believed to limit the need for repeated MBSS and the associated increased radiation exposure. This study has two main goals: 1) to determine the influence of patient medical diagnosis category, swallowing impairment severity, and clinician experience on radiation exposure time, and 2) to ascertain whether using a thorough, standardized data collection protocol during the MBSS, such as that associated with the MBSImP©™ [25], increases radiation exposure time relative to radiation exposure times reported in the literature. Once these goals have been achieved we can begin to understand the impact of various clinical factors on radiation exposure, and develop strategies to reduce exposure while maximizing diagnostic yield.

METHOD

Participants

Fluoroscopic exposure time (sec), medical diagnosis category, and clinician experience (novice versus experienced) were recorded based on a retrospective chart review of 739 adult swallow studies performed on 612 patients from September 2009 through September 2010. The median number of swallow studies performed per subject was 1, with a range of 1 to 6 studies. Data were obtained from 342 males and 270 females referred for MBSS examinations by trained speech-language pathologists (SLPs) at the Evelyn Trammell Institute for Voice and Swallowing at the Medical University of South Carolina (MUSC). Subjects' median age was 60 years, range = 18 to 96 years.

Standardized Protocol

Recently, Martin-Harris et al. [25] established a standardized, reliable and valid method for performing, describing, interpreting, and reporting observations of the type and severity of the swallowing impairment obtained during videofluoroscopic imaging – the Modified Barium Swallow Impairment Profile (MBSImP©™). The MBSImP©™ includes three integral standardized components: 1) training in swallowing physiology and impairment; 2) data collection protocol; and 3) scoring and interpretation. The MBSImP©™ standards were used for the clinical data collection protocol of the MBSS. MBSImP©™ standards were also used for the detection and documentation of swallowing impairment severity from the MBSSs. Eleven single swallows of standardized, commercial preparations of barium contrast agents (Varibar® E-Z-EM, Inc.) were obtained in the lateral and anterior-posterior viewing planes. Thin liquid barium (two trials of 5-ml via spoon, cup sip, and sequential swallows from cup), nectar-thick liquid barium (5-ml via spoon, cup sip, and sequential swallows from cup), honey-thick liquid barium (5 ml via spoon), pudding-thick barium (5 ml via spoon), and a one-half portion of a Lorna Doone shortbread cookie coated with 3-ml pudding-thick barium, were completed for each patient when appropriate, following the clinical guidelines. Consistencies judged to be unsafe based on observations of previous swallows are not given to patients. The scoring system takes these modifications into consideration as outlined in the following paragraph. To allow for flexibility in clinical decision making, compensatory strategies and behavioral methods were elicited as needed. Observations of esophageal clearance in the upright position were obtained in the anterior-posterior viewing plane.

Swallowing Impairment Severity

The MBSImP©™ [25] defines 17 components of oral, pharyngeal, and esophageal physiology. Each component is scored using a rank order severity scale based on unique physiologic observations of structural movement related to bolus flow from the MBSS recording. An overall impairment score for each component across all bolus consistencies and volumes was recorded based on a 3 to 5 point scale characterized by a distinguishable observation. When a particular texture level could not be administered because of patient safety issues related to concerns about significant aspiration or poor bolus clearance, the SLP rated that texture the most severe score for the individual component. These scores were used to develop the oral and pharyngeal totals. Oral components (1–6) and pharyngeal components (7–16) were summed for each individual subject to derive an oral total and pharyngeal total impairment score. Component 17 pertains to esophageal clearance and, therefore, is not included in the oral total or pharyngeal total scores.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Medical Diagnosis Category

Patients were categorized according to medical diagnosis obtained through the MBSS report. Specific diagnoses were grouped into the following broad categories: neurology; pulmonary; cardiac; ear, nose and throat (ENT); gastrointestinal (GI); and other.

Clinician Experience

Evaluating clinicians were speech-language pathologists with 1 to 17 years of clinical experience. Each clinician was trained according to MBSImP©™ standards to consistently and accurately (greater than 80%) score the MBSSs based on comparison to an expert clinician. The expert clinician (BMH) is a certified and licensed SLP with over 20 years of experience in the interpretation of MBSSs and who is a Board Recognized Specialist in Swallowing and Swallowing Disorders (BRS-S) by ASHA. Three novice clinicians and 7 experienced clinicians performed MBSSs at MUSC during the one year study period. At the start of the data collection period the three novice clinicians had 0 to 3 months of experience performing MBSSs. At this same time point, the maximum amount of experience for a single experienced clinician was 216 months with an average experience duration of 127 months for experienced clinicians.

Statistical Considerations

Because measures collected from the same patient over multiple swallow studies are correlated, all interval estimates and analyses accounted for the data’s lack of independence. Average fluoroscopic exposure times and corresponding 95% confidence intervals (CIs) were calculated for the entire sample, and separately for novice and experienced SLPs, and across diagnosis categories. Exposure time associations with clinician experience and medical diagnosis category were assessed using generalized estimating equations (GEEs) with identity link and exchangeable correlation structure. Specifically, we modeled exposure time as a linear function of clinician experience (or medical diagnosis category), an approach akin to ANOVA with adjustment for clustering of measures within patients.

We investigated associations between fluoroscopic exposure times and MBSImP©™ oral and pharyngeal total scores based on swallowing impairment data obtained from a subset of 158 randomly selected patients of the original 612. The sample size of 158 was selected to yield a minimum power of 83% to detect an approximate 3.5 sec increase in exposure time corresponding to a 1 unit score increase, supporting our belief that any extra radiation exposure is clinically significant. For subjects in the subsample with multiple swallow studies, oral and pharyngeal total scores were averaged to yield independent measures. We graphically examined the relationship between exposure time and oral or pharyngeal total scores using loess-smoothed scatter plots. We then compared average fluoroscopic times across quartiles of oral or pharyngeal total scores based on one-way ANOVA linear contrasts. Statistical significance was based on p-values < 0.05. All analyses were performed using SAS statistical software, version 9.2 [26].

RESULTS

Medical Diagnosis Category

Fluoroscopy time was not significantly associated with medical diagnosis category ($p = 0.10$). Mean fluoroscopy times and corresponding 95% CIs for medical diagnosis categories are displayed in Table 1.

Swallowing Impairment Severity

Oral Total (OT) and Pharyngeal Total (PT) scores were significantly associated with increased fluoroscopy time. Based on loess-smoothed plots, we observed a non-linear increase in fluoroscopy time as a function of OT or PT scores (figure not shown). We therefore compared differences in exposure times across quartiles of OT and PT. OT scores of 0–4 (quartile 1) were associated with statistically significantly shorter fluoroscopy times than OT scores of 5–20 (quartiles 2–4), p=0.0071, 0.0002, and 0.0033 respectively. PT scores of 11–22 (quartile 4) were associated with statistically significantly longer fluoroscopy times than PT scores of 1–10 (quartiles 1–3), p=0.0001, <0.0001, and 0.0346 respectively. PT scores of 7–10 (quartile 3) were also associated with statistically significantly longer fluoroscopy times than PT scores of 4–6 (quartile 2), p=0.0327. Figure 1 shows boxplots of fluoroscopy exposure times for quartiles of OT and PT.

Clinician Experience

Of the 739 MBSSs sampled, experienced clinicians conducted 497 MBSSs and novice clinicians conducted 242 MBSSs. For experienced clinicians, the average fluoroscopy time was 2.8 min with a 95% CI of 2.7 to 2.9 min. For novice clinicians, the average fluoroscopy time was 3.0 min with a 95% CI of 2.9 to 3.2 min. The difference in fluoroscopy time between experienced and novice clinicians was statistically significant (p = 0.037).

Standardized Protocol

Table 2 summarizes MBSS fluoroscopy exposure times reported in the ten identified published studies [10–17, 21–23]. Overall, average radiation exposure time using MBSImP©™ was 2.9 min with a 95% confidence interval of 2.8 to 3.0 min (range = 0.4 to 8.0 min), well within the range of exposure times reported in the literature.

DISCUSSION

The MBSS is the most frequently used method for swallowing function that provides physiologic evidence for targeted treatment, oral intake recommendations, and formulation of prognostic decisions. While implementation of the MBSS approach is supported by a large volume of empirical evidence, the fluoroscopic assessment includes x-rays and involves radiation exposure. Since fluoroscopy time is closely related to radiation exposure, it is important to understand how patient, clinician, and procedural factors influence fluoroscopy time. This study evaluated the impact of medical diagnosis category, swallowing impairment severity, clinician experience, and use of a standardized protocol on fluoroscopy time.

Medical Diagnosis Category

Medical diagnosis category did not increase fluoroscopy time. We had hypothesized that the medical diagnosis categories of neurology, GI, and ENT (specifically head and neck cancer patients) would be related to longer fluoroscopy times secondary to the perceived increased difficulty in performing MBSSs with patients of these diagnosis categories in comparison with pulmonary, cardiac or other diagnosis categories. The discrepancy between our hypothesized and actual results is likely because the severity of the impairment, not the medical diagnosis category, is the key factor. In our data, there was a broad range of impairment severity levels within medical diagnosis categories.

Swallowing Impairment Severity

Our results indicate that swallowing impairment severity increases fluoroscopy time. Specifically, we found that increased fluoroscopy time corresponded to an increase in

MBSImP©™ Oral Total (OT) and Pharyngeal Total (PT) scores. It is likely that higher severity is related to higher complexity of the swallowing impairment. Further, the potential for co-existing cognitive disorders and swallowing impairment may occur across medical diagnosis categories and were not accounted for in this review. Further investigation is warranted to determine the increase in fluoroscopy exposure time attributable to swallowing impairment versus cognitive impairment.

These results are different than our hypothesized results. We hypothesized that swallowing severity extremes (mild and severe impairments) would be related to short fluoroscopy times and that moderate swallowing impairments would be related to the longest fluoroscopy times. In fact, we found a statistically significant increase in fluoroscopy time for the most severe swallowing impairments compared with the mild impairments. Our operating premise was based on the theory that more compensatory strategies would be used with patients with moderately severe swallowing impairments than patients with mild or severe impairments. Compensatory strategies were used during the MBSS and were included in the overall fluoroscopy time, but our analysis did not account for the number and type of compensatory or treatment strategies attempted during the MBSS. Therefore, future studies are needed to assess the influence of the type and frequency of compensatory strategies on fluoroscopy time.

The results describing the influence of OT on fluoroscopy time revealed that the mildest severity levels (quartile 1) were associated with lower fluoroscopy times than all other severity levels. The components that make up the OT score include: lip closure, tongue control, bolus propulsion, bolus transit, oral residue and initiation of pharyngeal swallow. Most of these components are under volitional control and represent the part of the swallow that is most susceptible to patient level differences in volitional motor and cognitive abilities. It is logical that patients' difficulty with oral components of swallowing would have a direct influence on fluoroscopy time. It appears that there may be a threshold (above OT of 5) where these differences do not have such a direct influence on increasing fluoroscopy time. Further work is warranted to understand the influence of volitional control of oral components of swallowing on the rest of the swallowing mechanism.

The results reflecting the influence of PT on fluoroscopy time revealed that the highest severity levels were associated with greater fluoroscopy times than all other severity levels. The results also indicated differences between mid-levels of severity (quartiles 2 and 3). The components that make up the PT score include: soft palate elevation, laryngeal elevation, anterior hyoid excursion, epiglottic movement, laryngeal vestibule closure, pharyngeal stripping wave, pharyngeal contraction, tongue base retraction, and pharyngeal residue. Most of these components are not under volitional control and represent the part of the swallow that is least susceptible to patient level differences in volitional motor and cognitive abilities. It is well known that the severity of these components is modifiable with the introduction of compensatory strategies. It is possible that more time was spent trialing compensatory strategies in patients with higher levels of severity of the pharyngeal components thereby increasing fluoroscopy exposure time. Further work, however, is warranted to better understand the influence of pharyngeal impairment severity on increases in fluoroscopy time.

Clinician Experience

There was a statistically significant 12 sec difference in average fluoroscopy times comparing experienced and novice clinicians. The relatively small difference between experienced and novice clinicians may be due in part to the use of a standardized data collection protocol and focused training to target physiologic impairment associated with the MBSImP©™. From interviewing the novice clinicians, we learned that their standardized training in swallowing physiology and impairment and using a standardized protocol increased their confidence and efficiency in execution of the exam. Interpolating from Moro's results, an increase in fluoroscopy time of 12 sec relates to an increase of between 0.024 and 0.036 mSv [10]. While this related increase in radiation dose is small, according to the linear, no-threshold dose response for assessing stochastic effects of radiation exposure and the "As Low As Reasonably Achievable" (ALARA) principle, even small increases in radiation exposure are meaningful [18]. Further research should determine the "months of experience" threshold according to fluoroscopy time where the difference between a novice clinician and an experienced clinician dissipates. Once this is known, it may be useful to study methods to further lower the threshold and consequently reduce radiation exposure related to clinician experience.

Standardized Protocol

Our results indicate that the thoroughness of a standardized protocol does not lead to longer radiation exposure times even when compensatory strategies are included. We found an average fluoroscopy time for our MBSSs of 2.9 min (174 sec), well within the range of exposure times reported in the literature (150 sec to 1080 sec). Interpolating from the relationship Moro published, our mean of 174 sec relates to an effective dose of ~0.44 mSv [10]. This result opposes the perception that the use of a thorough standardized protocol for MBSS administration increases fluoroscopy time. The use of a standardized protocol associated with the MBSImP©™ that permits modifications based on patient severity and behavior, would likely relate to an even greater lifetime reduction of radiation exposure from MBSSs, since it may prevent repeat MBSSs due to insufficient findings from initial MBSSs. Anecdotally, the clear expectations associated with using a protocol allowed for efficient exams and coordination between radiologists and SLPs. Additionally, a standardized protocol allows for comparisons between and within patients, across SLPs and hospitals, and enables the use of valid and reliable MBSS observations as treatment outcome measures.

Limitations

There were three main limitations to this study: 1) limited number of influential factors considered, 2) retrospective nature of the study, and 3) generalizability of these findings to other standardized protocols or radiology/SLP teams. 1) Given the exploratory, preliminary nature of this study, we limited the factors to those most commonly believed to have a clinical impact (medical diagnosis category, swallowing impairment severity, use of a standardized, thorough data collection protocol, and clinician experience). There are potentially other significant factors that influence fluoroscopy time that we did not study. 2) This study was accomplished in a retrospective manner. It is possible that other factors that influence radiation exposure, specifically individual patient characteristics and compensatory trial information that was not available to use in sufficient detail retrospectively, would influence radiation exposure time. Further, the retrospective design did not allow for a true test of the value of standardization. A prospective study with a group using the standardized protocol and a control group would be needed to address this issue and should be considered when designing prospective studies on this topic. 3) These findings are strongly associated with use of the MBSImP©™ MBSS protocol. SLPs using the MBSImP©™ MBSS protocol have taken 21 CEUs of training, demonstrated reliability and have learned to quickly target strategies during the MBSS. Thus, these findings may not be generalizable to other MBSS protocols. Further, we recognize that there are individual differences due to the SLP-Radiologist teams and hospital procedures that may also impede the generalizability of these findings.

Conclusions

There are three main conclusions from this study: 1) medical diagnosis category does not influence fluoroscopy time, 2) swallowing impairment severity and SLP experience impact fluoroscopy time, and 3) using a thorough, standardized protocol, such as that associated with the MBSImP©™, does not increase radiation exposure. 1) Fluoroscopy time is not influenced by medical diagnosis category. This finding provides evidence to advocate for the use of a standardized MBSS data collection protocol, such as that associated with the MBSImP©™, across medical diagnosis categories. 2) It is important to be cognizant of the many factors that can influence radiation exposure for our patients. Care should be taken to reduce the influence of all possible factors not related to improved diagnosis yield according with the ALARA principle, such as the unvalidated practice of administering multiple non-standardized textures. Our earlier work demonstrated that physiologic swallowing impairment can be captured without implementation of repeated swallows of varied, non-standardized consistencies. 3) MBSS conducted using a standardized protocol, such as the one associated with the MBSImP©™, had radiation exposure times similar to those previously reported in the literature. While standardization of the MBSS with the MBSImP©™ data collection protocol does not increase radiation times, it likely provides a higher diagnosis yield and may reduce the need for repeat MBSSs. Research into the long term clinical implications of the use of the a standardized protocol, such as that associated with MBSImP©™, during the MBSS would provide stronger evidence to recommend the use of a protocol for both reduced radiation exposure and improved diagnosis yield.

Acknowledgments

This work was supported by the following grants: K23 DC005764-05 NIH/NIDCD, KL2 UL1 RR029880 NIH/NCRR, and Bracco Diagnostics. This work was also supported in part by the Biostatistics and Clinical Trials Shared Resource, Hollings Cancer Center, Medical University of South Carolina (P30 CA138313). Other financial or material support was provided by Evelyn Trammell Voice and Swallowing Institute and Northern Speech Services. Portions of this study have been presented at the 2011 Dysphagia Research Society Annual Meeting, San Antonio, Texas, March 2011.

References

1. Lovell SJ, Wong HB, Loh KS, Ngo RY, Wilson JA. Impact of dysphagia on quality of life in nasopharyngeal carcinoma. Head & Neck. 2005; 27(10):864–872. [PubMed: 16114007]
2. Palmer JB, Drennan JC, Baba M. Evaluation and treatment of swallowing impairments. American Family Physician. 2000; 61:2453–2462. [PubMed: 10794585]
3. Howden CW. Management of acid-related disorders in patients with dysphagia. American Journal of Medicine. 2004; 117(5A):44S–48S. [PubMed: 15478852]
4. Domench E, Kelly J. Swallowing disorders. Medical Clinics of North America. 1999; 83(1):97–113. [PubMed: 9927963]
5. Dodds WJ, Logemann JA, Stewart ET. Radiologic assessment of abnormal oral and pharyngeal phases of swallowing. AJR Am J Roentgenol. 1990; 154(5):965–74. [PubMed: 2108570]
6. Ekberg O, Sigurjonsson SV. Movement of the epiglottis during deglutition. A cineradiographic study. Gastrointest Radiol. 1982; 7(2):101–7. [PubMed: 7084590]
7. Martin-Harris B, Logemann JA, McMahon S, Schleicher M, Sandidge J. Clinical utility of the modified barium swallow. Dysphagia. 2000; 15(3):136–41. [PubMed: 10839826]
8. Ramsey GH, Watson JS, Gramiak R, Weinberg SA. Cinefluorographic analysis of the mechanism of swallowing. Radiology. 1955; 64(4):498–518. [PubMed: 14372088]
9. Logemann JA. Behavioral management for oropharyngeal dysphagia. Folia Phoniatr Logop. 1999; 51(4–5):199–212. [PubMed: 10450026]
10. Moro L, Cazzani C. Dynamic swallowing study and radiation dose to patients. Radiol Med. 2006; 111(1):123–9. [PubMed: 16623312]

11. McLean D, Smart R, Collins L, Varas J. Thyroid dose measurements for staff involved in modified barium swallow exams. Health Phys. 2006; 90(1):38–41. [PubMed: 16340606]
12. Hayes A, Alspaugh JM, Bartelt D, Campion MB, Eng J, Gayler BW, Henkel SE, Jones B, Lingaraj A, Mahesh M, Rostkowski M, Smith CP, Haynos J. Radiation safety for the speech-language pathologist. Dysphagia. 2009; 24(3):274–9. [PubMed: 19198942]
13. Wright RE, Boyd CS, Workman A. Radiation doses to patients during pharyngeal videofluoroscopy. Dysphagia. 1998; 13:113–115. [PubMed: 9513308]
14. Chan CB, Chan LK, Lam HS. Scattered radiation level during videofluoroscopy for swallowing study. Clin Radiol. 2002; 57(7):614–6. [PubMed: 12096861]
15. Weir KA, McMahon SM, Long G, Bunch JA, Pandeya N, Coakley KS, Chang AB. Radiation doses to children during modified barium swallow studies. Pediatr Radiol. 2007; 37(3):283–90. [PubMed: 17216172]
16. Zammit-Maempel I, Chapple CL, Leslie P. Radiation dose in videofluoroscopic swallow studies. Dysphagia. 2007; (1):13–5. [PubMed: 17024550]
17. Chau KH, Kung CM. Patient dose during videofluoroscopy swallowing studies in a Hong Kong public hospital. Dysphagia. 2009; 24(4):387–90. [PubMed: 19390892]
18. Nuclear Regulatory Commission Regulations. Title 10 Code of Federal Regulations, Part 20 Standards for protection against radiation. Section 20.1003 Definitions.
19. Bushberg, JT.; Seibert, JA.; Leidholdt, EM.; Boone, JM. The Essential Physics of Medical Imaging. 2. Philadelphia: Lippincott Williams & Wilkins; 2001.
20. Huda W. What ER radiologists need to know about radiation risks. Emerg Radiol. 2009; 16(5): 335–341. [PubMed: 19247699]
21. Crawley MT, Savage P, Oakley F. Patient and operator dose during fluoroscopic examination of swallow mechanism. Br J Radiol. 2004; 77(920):654–6. [PubMed: 15326042]
22. Steele CM, Murray J. Radiation awareness and practices among speech-language pathologists. Perspectives of Swallowing and Swallowing Disorders. 2004; 13:3, 2–4.
23. Martin-Harris B, Jones B. The videofluorographic swallowing study. Phys Med Rehabil Clin N Am. 2008; 19(4):769–85. [PubMed: 18940640]
24. Jorgensen JE, Rubenstein JH, Goodsitt MM, Elta GH. Radiation doses to ERCP patients are significantly lower with experienced endoscopists. Gastrointest Endosc. 2010; 72(1):58–65. [PubMed: 20421102]
25. Martin-Harris B, Brodsky M, Michel Y, Castell D, Schleicher M, Sandidge J, Maxwell R, Blair J. MBS measurement tool of swallow impairment – MBSImp: Establishing a standard. Dysphagia. 2008; (4):392–405. [PubMed: 18855050]
26. Hintze, J. PASS 2008. NCSS, LLC; Kaysville, Utah: 2008. www.ncss.com

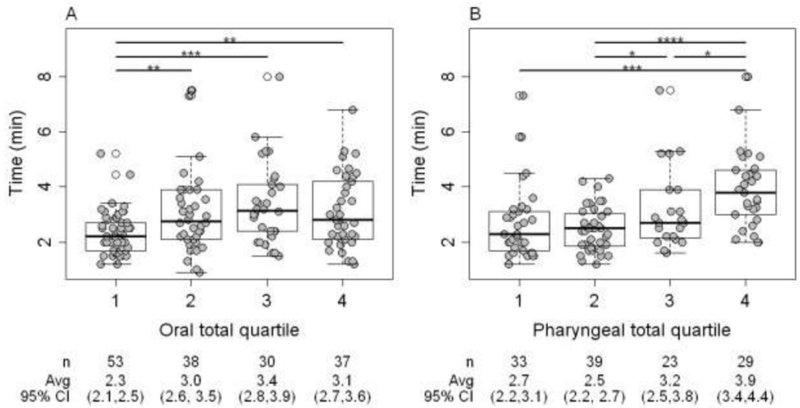

Figure 1.

Boxplots of fluoroscopy exposure times for quartiles of: (A) oral total scores, and (B) pharyngeal total scores. * p<0.05; ** p<0.01; *** p<0.001; **** p<0.0001. In panel B, sample sizes do not total 158 due to missing data.

Table 1

Average fluoroscopy times (min) and corresponding 95% confidence intervals by diagnosis category.

Diagnosis category	Number of patients	Number of swallow studies	Mean fluoroscopy time (min)	95% CI
Neurology	179	212	3.1	(2.9, 3.2)
Pulmonary	78	94	3.0	(2.7, 3.2)
Cardiac	12	13	2.7	(2.3, 3.1)
ENT	217	280	2.8	(2.7, 3.0)
GI	43	47	2.7	(2.2, 3.1)
Other	83	93	2.7	(2.4, 3.0)
Total	612	739	2.9	(2.8, 3.0)

Table 2

Characteristics of studies reporting fluoroscopy exposure time.

Author	Type of Study	N	Protocol	Results
Chan (2002)	Cross-sectional Observational	17	5ml and 10ml of thin and thick barium liquid, and congee sequentially using a long spoon. Each patient was fed by a relative. Lateral viewing plane only.	18 +/− 6 min
Chau (2009)	Cross-sectional Observational	398	Barium-mixed food of increasing viscosity (thin liquid, thick liquid, puree, solid) and volume (from 3, 5, 10, 15 ml to cup drinking). Presented by SLP in lateral and AP viewing planes.	4.23 +/− 2.56 min
Crawley (2004)	Cross-sectional Observational	21	SLP presented mixture of pureed food with barium, in various consistencies in lateral and AP viewing planes. Swallowing techniques implemented as needed.	Median 3.7 min, Range 2.5–4.3 min
Steele (2004)	Survey	121 survey respondents	Site dependent. Not specified.	Survey results – 22% 1–2 min, 30% 2–3 min, 29% 3–4 min, 16% don't know
Zammit-Maempel (2007)	Cross-sectional Observational	230	SLP presented controlled consistencies and bolus volumes: from thin liquids to muffin saturated with barium and from a teaspoon to drinking from a cup in lateral and AP viewing planes.	18 – 564 sec (median 2.85 min)
Hayes (2009)	Cross-sectional Observational	130	SLP presented various bolus consistencies (type of contrast material and amount dependent on individual study) in lateral and AP viewing planes.	Average 165sec, reported that typical fluoro time ranges between 30sec and 18 min.
Martin-Harris (2008)	Literature review	NA	Average times recorded during upper GI series.	Reported average fluoroscopy times for GI series of 3–5 min.
McLean (2006)	Cross-sectional Observational	3 hospitals over 8 clinical periods.	Hospital 1: The SLP delegated the traditional SLP role of feeding the patient with the contrast material during or just prior to fluoroscopy to the nurse. No protocol described. Hospital 2 and 3: No protocol described	Average between 3.0 to 3.6 min
Moro (2006)	Cross-sectional Observational	22	SLP presented boluses of contrast material in the form of a paste, which, according to patient conditions, was either liquid, semi-liquid, semi-solid or solid. Lateral and AP viewing planes obtained.	Exposure times ranged from 84sec to 306sec
Weir (2007)	Cross-sectional Observational	90	A standard protocol of food and fluid trials included at least two trials each of puree and	Average 2.48 +/− 0.81 min

Author	Type of Study	N	Protocol	Results
			lumpy semisolids from a spoon, a self-fed chewable solid texture, and two individual boluses or continuous drinking of thin fluid, nectar and thick fluids from a bottle or cup presented by SLP.	
Wright (1998)	Cross-sectional Observational	23	A standardized range of liquids varying in viscosity and some solid food were presented for the analysis of pharyngeal swallow. Lateral viewing plane only.	Average 286sec ranging from 32–497sec