Effect of Pulse Rate on Judgments of Airway Compromise Events during Infant Modified Barium Swallow Studies

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Abstract:
Purpose: This research project sought to determine the effect of pulse rate on judgments of moderate to severe airway compromise events during infant MBSS.
Method: This retrospective analysis investigated potential differences in Penetration Aspiration Scale (PAS) scores for swallows viewed at three different simulated pulse rate conditions by providing video files for review that featured 30 images per second (ips), 15 ips, and 7.5 ips. Analysts who were trained to achieve high consensus scored 20 different infant swallows recorded during MBSS at each of the simulated pulse rate conditions using the PAS.
Result: Significant differences in PAS scores were found between infant MBSS reviewed at 30 pps and simulated 7.5 pps, with scores lower at simulated 7.5 pps, indicating analysts perceived less severe airway compromise events during the infant MBSS reviewed at lower pulse rates.
Conclusion: The results from this research study indicate that the accurate identification of airway compromise events is affected by the pulse rate applied during the infant MBSS.

Key Words: Infant, Modified Barium Swallow Study, Pulse Rate, Aspiration, Dysphagia, Videofluoroscopic Swallow Study

1. Introduction:

Instrumental assessment is necessary for the accurate diagnosis of swallowing dysfunction and determination of the presence of airway compromise events (laryngeal penetration and aspiration) associated with swallowing dysfunction.[1] Instrumental assessment for the determination of swallowing dysfunction may be accomplished with modified barium swallow study (MBSS),[2,3] an appropriate exam for documenting swallowing dysfunction in pediatric patients because it is the only instrumental assessment that provides visualization of the oral cavity, pharynx, larynx, and upper esophagus during the dynamic process of swallowing. This feature makes the MBSS the ideal procedure for assessing swallowing function and documenting the presence of airway compromise events before, during, or after the swallow.[2,4,5]

Infants use a sophisticated, highly coordinated process of suckling/sucking, swallowing, and respiration to safely consume enough calories to support their rapid growth and development. The suck/swallow/breath ratio is typically described as 1:1:1. This highly coordinated sequence requires that the infant suckle/suck the liquid from the nipple, swallow with interruption to respiration, and then continue respiration in a continuous rhythmic fashion. Disruption to that sequence can result in airway compromise.[6] Airway compromise is an important feature of swallowing dysfunction that MBSS is designed to detect.

The MBSS is a critical tool for providing accurate diagnosis of swallowing dysfunction in pediatric populations, but it requires the same types of precautions as other radiological examinations that use ionizing radiation.[7] The American College of Radiology's position on radiation dose in pediatric patients is that it should be "as low as reasonably achievable" (ALARA).[8] The mean effective dose for children during MBSSs was most recently estimated to be 0.0826 +/- 0.0544 mSv based on the analysis of 90 consecutive MBSS using pulsed fluoroscopy performed at 15 pulses per second. The effective dose was correlated with screening time, dose area product, and individual child and procedural variables.[9] To reduce radiation dose during fluoroscopy procedures the American College of Radiology recommends providing pulsed fluoroscopy when possible, shielding body parts not being imaged, and only using fluoroscopy tests when needed.[8]

Using pulsed fluoroscopy during infant MBSS can have the undesirable effect of reducing the number of unique images captured during the swallow. Assuming pulse rate is set to 30 pulses per second (pps) and the fluoroscopy machine is synchronized properly with an image capture system set with a rate of 30 frames per second, then there is no discrepancy between the unique images available to review at 30 pps as compared to unique images available to review from continuous fluoroscopy recorded at 30 frames per second (fps). However, when pulses per second is reduced to 15 or 7.5 per second, then the number of unique images captured at North American video recording standards of ~30 frames per second is significantly reduced. Considering the complete infant swallow sequence from mouth to upper esophagus takes less than one second,[10] when pulse rate is reduced to 15 pulses per second (pps) or 7.5 pps from 30 pps, the motion of the swallowed boluses appears less fluid and more like that seen in stop motion animations.[11] There is not current consensus on the effect of reducing pulse rate and its impact on the ability of clinicians to accurately determine events of airway compromise during the MBSS. Originally, Hiorns and Ryan (2006) reported that 15 pps was sufficient to capture episodes of aspiration that occur during MBSS performed on infants less than one year of age.[12] More recently, Cohen (2009) concluded that decreasing fluoroscopic pulse rates during MBSS was not advisable as a way to decrease radiation dose due to the rapid appearance and disappearance of supraglottic penetration in those children with swallowing dysfunction.[13] Cohen reported that reducing the fluoroscopic pulse rate below 30 pps would result in the non-detection of laryngeal penetration in pediatric patients during MBSS.[13] Both of the previous studies used methodology that counted the number of frames during which airway compromise events were present and drew conclusions about appropriate pulse rate based on those observations.

2. Purpose:

The current study sought to determine whether accurate identification of airway compromise events (laryngeal penetration and aspiration) from infants described as having moderate to severe dysphagia during infant MBSS was influenced by the lowering of pulses per second. Specifically, the authors sought to determine whether problematic swallowing events would be missed or perceived as less severe at lower image acquisition rates.

3. Method:

3.1 Participants

Retrospectively, 20 infant MBSSs were randomly selected from a potential participant pool of MBSS performed at a large children's hospital (LCH) in the United States of America during 2008. All MBSS at LCH in 2008 were performed with continuous fluoroscopy and recorded in the lateral view. A properly collimated General Electric (GE) radiographic/fluoroscopic unit was used and fluoroscopic images were recorded to a Digital Swallowing Workstation (Model 7200; Kay Elemetrics, Lincoln Park, NJ) using a digital scan converter to electronically record them at 29.97 frames per second and save them in an audio video interleave format. For inclusion in the participant pool, infants had to be between birth and four months of age and have received clinical impression of moderate-severe oropharyngeal dysphagia based on clinical review of MBSS by a qualified speech-language pathologist and radiologist at LCH. Demographic characteristics of study participants are presented in Table 1. All participants were de-identified and coded for review in this study to protect privacy. IRB approval was received from The University of Alabama and The University of Tennessee Health Science Center prior to study initiation. This work was funded by the University of Alabama's College Academy for Research, Scholarship, and Creative Activity (CARSCA) grant during the fall 2013 funding cycle.

Table 1: Participant demographic information

Participant no.	Age in weeks	Sex	Reported Diagnostic Categories	Reason for Referral
1	5	F	Respiratory, Gastrointestinal	Rule out dysphagia
2	1	F	None	Poor feeder
3	12	M	None	Coughing, choking, gagging with feeding
4	6	M	Respiratory	Rule out dysphagia
5	16	M	History of prematurity, Respiratory, Gastrointestinal, Neurological, Bacterial Infection	Rule out dysphagia
6	4	M	Neurological, Metabolic	Rule out dysphagia
7	7	M	Respiratory, Gastrointestinal	Choking with feeding
8	15	M	Respiratory, Gastrointestinal	Choking with feeding
9	11	M	Respiratory, Cardiac, Neurological	Choking with feeding
10	7	M	History of prematurity, Respiratory	Rule out dysphagia
11	2	F	History of prematurity, Cardiac, Genetic	Oxygen desaturation with feeding
12	3	M	History of prematurity, Respiratory, Cardiac,	Rule out dysphagia
13	2	M	Respiratory	Rule out dysphagia
14	3	M	Renal	Wheezing with feeding
15	14	F	Gastrointestinal, Neurological	Coughing and congestion with feeding
16	16	F	Respiratory, Gastrointestinal	Coughing and congestion with feeding
17	4	F	Cardiac	Oxygen desaturation with feeding
18	6	M	Respiratory, Cardiac,	Congestion after feeding
19	12	F	History of prematurity, Respiratory, Cardiac, Genetic, Neurologic, Metabolic	Oxygen desaturations and bradycardia with oral feeding
20	16	F	Respiratory, Cardiac, Neurologic	Poor feeding

Infants undergoing MBSS were seated, semi-upright, in a Tumbleform chair and were viewed in the lateral projection. Each infant was presented with Varibar Thin Liquid Barium (Bracco Diagnostics Inc, Monroe Township, NJ) (target viscosity of 4 centipoise, viscosity range <15 centipoise) and was then presented with compensatory, thickened liquid bariums if swallowing function observed indicated its use. All liquids were prepackaged with standard viscosity targets and manufactured by Bracco Diagnostics Inc. (Monroe Township, NJ). The thin liquid barium required reconstitution from powder form and clinicians followed manufacturer's instructions to prepare standard thin liquid barium fluid. This controlled for any variability in liquid consistency presented. Liquids were offered from a Similac (Abott Laboratories, Abott Park, IL) disposable volu-feeder bottle with standard Similac, disposable one-hole nipple. Compensatory strategies were introduced as necessary dependent on baseline performance.

The participants included in this study all underwent MBSS as described above and had episodes of laryngeal penetration and/or aspiration recorded during their study as determined by a qualified speech-language pathologist and radiologist. A sequence of three swallows of thin liquid barium from each participant's MBSS, at least one of which demonstrated a laryngeal penetration and/or aspiration event, was randomly chosen to analyze for this study. In this study, 53.3% (32/60) of the swallows demonstrated an episode of laryngeal penetration and 10% (6/60) of the swallows indicated an episode of aspiration as determined by a trained analyst. Out of these three swallows, for the purposes of this study, the most severe example of laryngeal penetration and/or aspiration as scored with the Penetration Aspiration Scale (PAS) [14] was chosen for further analysis. In cases where all three swallows received the same PAS score, the score from the first swallow was chosen for further analysis.

3.2 Recordings

To create simulated 15 pps and 7.5 pps conditions, the original 30 images per second (ips) recordings were downsampled to 15 ips by deleting every other frame with Adobe After Effects (Adobe Systems, San Jose, CA). The 15 ips recordings were then downsampled to create 7.5 ips recordings by deleting every other frame from the 15 ips recordings. A similar method of downsampling videos had been used in previous research studies examining the effect of pulse rate on measures of swallowing impairment in adults.[11] The files were again saved in an audio video interleave (AVI) format after downsampling. The same 20 swallows were reviewed under three different simulated pulse conditions (30 ips, 15 ips, and 7.5 ips). To reduce analyst bias, the identifying properties (whether 30, 15, or 7.5 ips condition) were removed and analysts were blinded to the purpose of the study and the simulated pulse condition with which they were scoring. Additionally, the videos were watched in a randomly assigned order. Although the same effect could and has been achieved in previous research (Hiorns & Ryan, 2006; Cohen, 2009) by counting the number of frames on which laryngeal penetration and aspiration events are present on screen, the authors sought to determine if reducing pulse rate resulted in an analyst perceiving a difference in airway compromise events and therefor, the current methodology was employed as it provides novel and useful information on the effect of lowering pulse rate on actual judgments of airway compromise. Additionally, the act of counting may introduce additional subjectivity and/or bias into the analysis and scoring of swallows.

3.3 Measures

In this study, the Penetration Aspiration Scale (PAS) was used to measure airway compromise events (see Table 2). The PAS assigns a value of one to eight to each swallow to indicate the degree of airway compromise (none (1) or laryngeal penetration (2-5) or aspiration (6-8)) observed during the swallow.[14] The eight point PAS approximates ordinality and intervality, allowing for statistical analysis requiring interval-level variables.[15] It has also been shown to be a reliable tool for describing penetration and aspiration events in pediatric populations.[16]

Table 2: Penetration Aspiration Scale (PAS) definitions

Score	Category	Description
1	No airway compromise	Bolus does not enter the airway
2	Laryngeal penetration	Bolus enters the airway, remains above the vocal folds & is ejected from the airway
3	Laryngeal penetration	Bolus enters the airway, remains above the vocal folds & is NOT ejected from the airway
4	Laryngeal penetration	Bolus enters the airway, contacts the vocal folds & is ejected from the airway
5	Laryngeal penetration	Bolus enters the airway, contacts the vocal folds & is NOT ejected from the airway
6	Aspiration	Bolus enters the airway, passes below the vocal folds & is ejected into the larynx or out of the airway
7	Aspiration	Bolus enters the airway, passes below the vocal folds & is NOT ejected from the trachea despite effort
8	Aspiration	Bolus enters the airway, passes below the vocal folds & No effort is made to eject

Note: Score descriptions taken from original definitions of PAS[14]

Two analysts (primary analyst and secondary analyst) were trained to achieve a high level of consensus using the Penetration Aspiration Scale (PAS) [14] by a speech-language pathologist (credentialed analyst) with previous experience using the PAS in pediatric clinical settings. Training began by rating penetration and aspiration events from adult MBSS with the PAS on commercially available training packages and then transitioned to practice collecting measures on de-identified pediatric MBSS. Videos were reviewed using QuickTime software (Version 7, Apple, Cupertino, CA) and were reviewed with frame-by-frame analysis and/or in slow motion, forward or backwards, and as many times as necessary for analysts to feel confident in their ratings. Analysts completed the first viewing of all of the videos over the course of 5 days; being allowed to break whenever they felt it was necessary. All recordings were viewed under constant conditions on the same computer, a 27-inch iMac, with the lights in the room off. Analysts did not adjust brightness or color features on the computer screens while scoring the swallows and no magnification software was used. During training and prior to beginning this project, the two analysts achieved high percent agreement (90% or greater) with each other and with the credentialed analyst for scoring airway compromise events during MBSS with the PAS.

For this study, the primary analyst watched and scored all of the swallow sequences and the secondary analyst watched 20% of the recordings to ensure agreement ($\kappa_W = .935$, $p < .0001$). The reviewers were blinded to each other's ratings. To check for agreement, the primary analyst waited at least two weeks and then reviewed 20% of the videos again ($\kappa_W = .919$, $p < .0001$). Finally, the primary analyst's scores were compared to the credentialed analyst's scores for all recordings ($\kappa_W = .897$, $p < .0001$).

3.4 Analysis

The primary rater's data for 20 recorded swallow sequences of three swallows were reported and the most severely rated swallow out of three was chosen for analyses to ensure that the impact of pulse rate on clinically rated moderate to severe episodes of laryngeal penetration and aspiration were investigated in accordance with the stated purpose of this research. Each swallow sequence was viewed under three different simulated pulse conditions (30 ips, 15 ips, and 7.5 ips). At the most detailed level, ratings fell into eight ordered PAS categories. The most powerful analysis involves treating the eight ordered PAS categories as an interval scale with three repeated measures for each case (30 ips, 15 ips, 7.5 ips). This analysis was conducted with a Linear Mixed Model (LMM) framework, implemented in Statistical Analysis System (SAS) PROC MIXED (SAS Institute Inc., Cary, NC), treating simulated pulse rate (images per second) as a categorical repeated measure; the model was fit using a compound symmetry covariance structure. Because of the small sample ($N = 20$), the authors consider results where $.05 \leq p < .10$ as achieving marginal statistical significance.

It is recognized, however, that disagreement exists about whether the response variable can be treated as interval or even as ordinal.[15] Thus, a series of sensitivity analyses, which increasingly relaxed assumptions about the response variable, were conducted. First, the LMM analysis was run again, collapsing the eight ordered categories of the response variable into three ordered categories (no airway restriction, penetration, and aspiration) because this represents the clinical framework by which airway compromise events are most often reported. This analysis again treated the three-category response scheme as interval. Second, (a) the eight-category response variable and (b) the three-category response variable were treated as ordinal. For these analyses, a Generalized Estimating Equations (GEE) framework was used, implemented in SAS PROC GENMOD (SAS Institute Inc., Cary, NC), with a multinomial error distribution and a cumulative logit link function. Third, a generalized linear mixed model (GLMM) was implemented in SAS PROC GLIMMIX (SAS Institute Inc., Cary, NC), to conduct a multinomial logit analysis of both the eight-category and the three-category response variable; a multinomial response distribution and a generalized logit link function were specified. It is not possible to estimate *R*-side effects with an unordered multinomial distribution in SAS PROC GLIMMIX (SAS Institute Inc., Cary, NC), therefore the responses were not treated as repeated measures. All post-hoc analyses used a Tukey-Kramer adjustment to standardize multiple comparisons at $\alpha = .05$. Detailed results for the primary analysis are reported; the results of the sensitivity analyses are summarized.

4. Results:

First, frequencies for the analyzed swallows on the PAS at each ips rate can be found in Table 3. The LMM analysis for the (interval) eight-category PAS response variable showed a significant effect for images per second/simulated pulse rates (F (2,38) = 4.25, $p = .022$; see Table 4-A). A post-hoc analysis (see Table 4-C) showed that the 30 ips — 7.5 ips difference was statistically significant (adj. $p = .029$) and that the 15 ips —7.5 ips difference was marginally significant (adj. $p = .062$); the 30 ips —15 ips difference in severity of ratings was not significant (adj. $p = .740$). Mean ratings for each of the three speeds are shown in Table 4-B. The severity of ratings generally increased as ips rate increased.

Table 3: Frequencies of PAS scores

		Analyzed Swallow		
Category	score	30 ips	15 ips	7.5 ips
No airway compromise	1	0	0	1
Penetration	2	9	8	10
	3	0	1	0
	4	0	0	0
	5	5	6	6
Aspiration	6	0	0	0
	7	0	0	0
	8	6	5	3

Note: n = 20 for each pps rate; ips = images per second

Table 4: Effect of pulse rate on severity of ratings (eight-category)

Panel A						Panel B
Effect	Estimate	Standard Error	*t*	*df*	*p*	Mean
intercept	3.750	0.538	6.97	19	<.0001	
30 ips	0.800	0.299	2.68	38	.011	4.55
15 ips	0.700	0.299	1.34	38	.025	4.45
7.5 ips (reference)						3.75

Panel C						
Effect	Estimate	Standard Error	*t*	*df*	*p*	adj. *p*
30 ips — 15 ips difference	0.100	0.299	0.33	38	.739	.940
30 ips — 7.5 ips difference	0.800	0.299	2.68	38	.011	.029
15 ips — 7.5 ips difference	0.700	0.299	2.34	38	.025	.062

Note: ips = images per second

The first three types of sensitivity analyses show results that are similar to, but generally weaker than, those reported in Table 4. The GEE analysis using three response categories, treated intervally, showed a statistically significant difference for 30 ips — 7.5 ips (adj. p = .029); neither 15 ips —7.5 ips difference (adj. p = .124) nor the 30 ips —15 ips difference (adj. p = .783) were statistically significant.

For the ordinal GEE analysis using eight response categories, the 30 ips — 7.5 ips difference achieved statistical significance (adj. p = .047) and the15 ips — 7.5 ips difference approached significance (adj. p = .063); the 30 ips —15 ips difference was not significant (adj. p = .976). The ordinal GEE analysis using three response categories yielded a 30 ips — 7.5 ips difference that approached statistical significance (adj. p = .094); however, neither the 15 ips —7.5 ips difference (adj. p = .172) nor the 30 ips —15 ips difference (adj. p = .572) was significant. In all of these analyses, greater ips rates were associated with more severe ratings.

Finally, the nominal analysis using a multinomial logistic GLMM showed no differences among the three simulated pulse rates using either the eight-category response variable (omnibus p = .995) or the three-category response variable (omnibus p = .895).

5. Discussion:

This study showed statistically significant differences in PAS ratings between swallows during the two simulated pulse conditions utilizing 30 ips and 7.5 ips conditions, and differences between the two simulated pulse conditions utilizing 15 ips and 7.5 ips were marginally significant. PAS scores from the simulated 30 pps condition compared to the simulated 7.5 pps conditions were higher, as were PAS scores from the simulated 15 pps condition compared to the simulated 7.5 pps condition, revealing that the analyst assigned a higher (more severe airway compromise event) score when reviewing swallows with 30 ips than when reviewing swallows with 15 and 7.5 ips. This indicates that as the number of unique images available decreases, as it does when utilizing pulse rates below 30 pps, airway compromise events appear to reviewers to be less severe.

These results for the 30 ips — 7.5 ips LMM comparison held when the eight-point PAS scale was treated as ordinal, and when it was collapsed into a three-point scale (no airway restriction, laryngeal penetration, and aspiration) treated both intervally and ordinally (although the latter achieved only marginal significance). The marginally significant 15 ips — 7.5 ips LMM comparison only held when the eight-category PAS scale was treated as ordinal; none of the three-category comparisons of these speeds produced significant differences. The finding indicates that when the ips rate is reduced from 30 to 7.5, enough of the swallowing information is lost to affect the accuracy of reporting airway compromise events (laryngeal penetration and aspiration); it also suggests that this may be the case when ips is reduced from 15 to 7.5, although this conclusion requires more exploration, with a larger sample. Thus, the perception of airway compromise severity has the potential to affect clinical recommendations for oral intake in infant populations with dysphagia that results in airway compromise.

One case in the sample changed PAS categories (moving from aspiration to laryngeal penetration) from 30 ips to 15 ips. However, 15% of the sample's identified PAS category changed from 30 ips to simulated 7.5 ips, a significant shift. Here, two cases shifted from aspiration to laryngeal penetration, and one case shifted from laryngeal penetration to no airway restriction, with one additional shift within laryngeal penetration (score of 5 to a score of 2). It is important to note that these shifts were toward a less severe airway compromise event, which could impact the clinical impression of dysphagia severity and recommendations for treatment.

The information reported here should guide clinicians and radiologists in determining the risk to benefit ratio of lowering the radiation exposure by decreasing the pulse rate at the expense of diagnostic accuracy. While the results of this analysis do not completely confirm the previous findings of Cohen (2009) and Bonhila and colleagues (2013) who both reported that 30 pps was necessary to accurately identify episodes of airway compromise that occur during MBSS, what is clear is that clinicians and radiologists should be concerned about the accuracy of their airway compromise conclusions when using pulsed fluoroscopy below 30 pps (15 and 7.5 pps) because it would provide less than 30 unique images per second. The clinician and radiologist must also consider the impact of lowering pulse rate on their ability to accurately identify temporal and physiologic features of swallowing function during the MBSS, which was not explored in the current research study.

Including the results of this study, all of the available information on this topic definitively supports using a pulse rate of at least 15 pps when performing infant MBSS [12-13]. However, given all that remains to be determined about the impact of reduced pulse rate on identifying physiologic and temporal features of swallowing dysfunction and the known morbidity and mortality associated with recurrent airway compromise in pediatric populations [17,18], the authors argue that until the complete impact of reducing pulse rate is understood clinicians and radiologists should advocate for the use of 30 pps. Advocating for the use of 30 pps ensures the accurate reporting of airway compromise events by trained professionals. Clinically, dysphagia that results in laryngeal penetration is treated differently, usually with less dietary restrictions, than dysphagia that results in aspiration. Therefore, interpretation of airway compromise events from MBSS performed at pulse rates below 30 pps has significant potential to impact the clinical recommendations regarding management of the identified dysphagia. Further, the authors propose that performing MBSS at pulse rates below 30 pps when evidence exists that the lowered pulse rate impacts the perception of airway compromise severity, which has significant potential to impact the way in which the infant's dysphagia is managed, violates the spirit of the ALARA principle [8] as it exposes the infant to radiation without the benefit of accurate results. The results of this study support the immediate and necessary continued investigation of the effect of pulse rate on the diagnostic accuracy of the infant MBSS beyond just describing its impact on airway compromise events.

5.1 Limitations

There were inherent limitations to this study. This project relied on retrospective analysis of previously recorded MBSS. Common sources of bias from retrospective analysis include subject selection and observational bias. To control for these sources of bias, the first author randomly selected participants from a qualified pool of potential participants chosen against established inclusion and exclusion criteria and collected new observations (PAS scores) from the previously recorded MBSS. To reduce the possibility of bias, analysts were trained by the author on use of the PAS before they reviewed the previously recorded MBSS. The participants for this research project were identified from a limited sample from the same institution. This fact introduces the potential for institutional bias. Future studies should draw participants from multiple institutions to avoid this bias. The participants for this study all had MBSSs that revealed a clinical impression of moderate – severe dysphagia. This is not a complete representation of the continuum of swallowing dysfunction documented amongst infant participants with swallowing dysfunction. Those with milder swallowing dysfunction may present with less severe airway compromise and those events should also be evaluated for potential impact of pulse rate on judgments of severity in future studies.

The authors acknowledge also, the questioning of this scale being treated ordinally and/or intervally for statistical analysis. McCullough et al. (1998) found that a score of 5 and 6 (notably, reflecting different collapsed PAS categories) have been interchanged with respect to their severity. In our study, no swallows were scored with a PAS category of 6. This was not planned and may not be found in other similar studies; but in this study, the result strengthens the argument for treating this scale as interval, and for using the more powerful statistical analysis appropriate for interval data.

Finally, this study used a relatively small sample size. Future studies should aim to increase sample size. While the authors found marginal significance in some analyses, it is reasonable to expect that with additional statistical power created by additional participants, the results would be strengthened.

6. Conclusion:

The accurate identification of airway compromise events is just one important feature of identifying swallowing dysfunction during infant MBSS. This project does not begin to explore the other, potentially detrimental, impacts that reducing pulse rate may have on determining temporal features of swallowing dysfunction (such as oral transit time) and/or physiologic features of swallowing dysfunction (such as base of tongue to posterior pharyngeal wall contact). These are also important considerations for determining swallowing dysfunction that need to be studied with future research because the MBSS is not just a study for determining airway compromise. This research project offers relevant data to the discussion of pulse rate parameters for infant MBSS as it establishes that MBSS performed in young infant populations with moderate to severe oropharyngeal dysphagia must not be performed at a videofluoroscopic pulse rates less than 15 pps to ensure accurate identification of airway compromise events.

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