Delayed Initiation of the Pharyngeal Swallow: Normal Variability in Adult Swallows

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Purpose: The purpose of this investigation was to determine bolus head timing and location relations with the onset of hyoid movement at the initiation of the pharyngeal swallow and at the onset of swallow-related apnea.

Method: Bolus head timing and location and the timing of swallow-related apnea were recorded from frame-by-frame analyses of 5-ml single liquid swallows using dual-modality videofluoroscopy and nasal airflow recordings in 82 consecutive, healthy volunteers. The presence, depth, and response to airway entry were also recorded and related to the bolus head location and the onset of hyoid movement.

Results: The majority of participants—80% on at least 1 trial—produced the onset of hyoid movement at pharyngeal swallow initiation after the bolus head passed the posterior angle of the mandible. There was a trend in older participants for later onset of hyoid movement and onset of apnea relative to bolus head arrival at the posterior angle of the mandible.

Conclusion: Although entry of the bolus head into the pharynx prior to hyoid movement may result in a threat to the laryngeal airway, these data demonstrate that a "delay" by itself cannot be assumed to indicate a disordered swallow without coexisting impairments of swallowing physiology.

KEY WORDS: pharyngeal delay, breathing, swallowing, deglutition, apnea

Bolus location relative to swallowing timing has been studied for more than 50 years. Advances in radiographic imaging, video recording, temporal measurement, and analytical tools have afforded researchers the ability to describe bolus flow patterns relative to the timing of structural movements that occur during normal swallowing. One primary goal of this line of research was to clarify the relevance of deviations from these normal patterns in patients with dysphagia. It has been well established that airway protection during swallowing requires coordination of bolus flow with the timing of structural movements that protect the airway and propel the bolus through the oropharynx and cervical esophagus. Observations of premature entry of the bolus into the pharynx prior to the onset of certain structural movements during swallowing have been described as representing delays in the initiation of the pharyngeal swallowing mechanism. The underlying causes of the delay have been the focus of study and may represent sensory deficits in the posterior oral cavity, oropharynx, and supraglottic larynx. Delay may also be associated with slowness or discoordination of tongue motion that is contributory to the onset of pharyngeal events (Logemann, 1997). Despite the cause and contributions of delayed onset of pharyngeal swallowing events to airway protection and bolus clearance, the operational definitions that have

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been used to indicate a delayed swallow vary and lead to confusion in the clinical interpretation of its functional relevance.

Investigators have historically characterized a delay in the pharyngeal swallow by associating timing of structural movement (i.e., hyoid motion) with the location of the leading edge of the bolus, or bolus head. Ardran and Kemp (1952) reported that a normal swallow viewed in a lateral radiographic plane was characterized by "a momentary pause [during which] a little of the barium spills over the lateral pharyngo-epiglottic folds into the lateral food channels but the bulk of the bolus is held upon the epiglottis" (p. 406). Logemann (1983) first described instances when the bolus was "falling over the base of the tongue" (p. 74) prior to the initiation of the "swallowing reflex" (pp. 24–26). This radiographic sign was defined as a delay in the initiation of the swallowing reflex. Robbins, Hamilton, Lof, and Kempster (1992) used the novel term *stage transition duration* to denote the time interval between the point when the bolus first passes the ramus of the mandible and the onset of hyoid excursion. Any difference between these temporal points implicated a delay in initiation of the pharyngeal swallow. Perlman, Booth, and Grayhack (1994) related delay to hesitation of the bolus in the pharyngeal recesses. They stated that the swallow was not delayed until after the bolus had entered the valleculae and remained there for 1 s prior to swallow initiation. Perlman et al. also measured the amount of time the bolus sits or "dwells" in the valleculae before the pharyngeal swallow is initiated as an indicator of swallow delay. After years of further study, Logemann (1997) explained: "When the head [the leading edge] of the bolus passes the tongue base, the point where the lower edge of the mandible crosses the tongue base … the pharyngeal swallow should have begun" (pp. 91–92). Regardless of what it is labeled, the observation of delayed initiation of the pharyngeal swallow has historically been considered a pulmonary threat with the potential for airway penetration with or without aspiration.

These early studies of delay in the onset of the pharyngeal swallow often used controlled bolus volumes of barium that were administered by a syringe or spoon. Exploratory work in our laboratory and clinical observations, however, have demonstrated varied onset in the timing of swallowing events when natural cup drinking of small volumes was used as the swallowing task (Martin-Harris, Brodsky, et al., 2005; Martin-Harris, Brodsky, Price, Michel, & Walters, 2003; Martin-Harris, Michel, Castell, 2005). Furthermore, larger volume (20–50 ml) and sequential straw- or cup-drinking tasks have shown evidence of advanced entry of the bolus head into the hypopharynx prior to onset of hyoid excursion (Chi-Fishman & Sonies, 2000; Daniels & Foundas, 2001; Dozier, Brodsky, Michel, Walters, & Martin-Harris, 2006). Normative data describing swallowing delay have not typically used cup-drinking methods. Therefore, clinicians may misinterpret the meaning of radiographic findings if these clinicians were to apply existing norms to cup-drinking tasks.

Breathing and swallowing coordinative patterns, which are key to airway protection during swallowing, have also been shown to differ when comparing single bolus swallows to sequential swallowing tasks (Dozier et al., 2006). Within the past 2 decades, research has extensively addressed and described the breathing patterns associated with swallowing (e.g., Hirst, Ford, Gibson, & Wilson, 2002; Hiss, Treole, & Stuart, 2001; Klahn & Perlman, 1999; Martin, 1991; Martin, Logemann, Shaker, & Dodds, 1994; Martin-Harris et al., 2003; Martin-Harris, Brodsky, et al., 2005; Preiksaitis, Mayrand, Robins, & Diamant, 1992; Selley, Flack, Ellis, & Brooks, 1989a, 1989b). Remarkably, the coordination between breathing and swallowing in the context of delayed initiation of the pharyngeal swallow has not been widely addressed in the literature (Morton, Minford, Ellis, & Pinnington, 2002). It might be predicted, therefore, that nonnormal coordination of breathing and swallowing, specifically the timing and duration of swallow-related apnea, would lead to penetration and, possibly, aspiration of ingested materials. A patient may continue inhaling during the delay period, and the negative pressure from this inhalation pulls the bolus into the airway. Nilsson, Ekberg, Bülow, and Hindfelt (1997) showed that patients who either penetrated or aspirated during the swallow had longer pharyngeal transit times and relatively shorter periods of swallow-related apnea. Whereas duration is one aspect that should be considered for study, the onset and offset of swallow-related apnea relative to bolus location also appear to be critical features of safety.

This study was designed to address the following specific aims during a 5-ml cup-drinking task observed using videofluoroscopy:

1. Test for difference in time between bolus head arrival at the posterior angle of the mandible and the onset of the brisk, angular movement of the hyoid.
2. Describe bolus head location at the time of the brisk, angular movement of the hyoid from its stable position (i.e., onset of the pharyngeal swallow).
3. Detail any difference in temporal and bolus location measures with aging.
4. Describe the timing between the onset of the obligatory apneic pause and the arrival of the leading edge of the bolus at the posterior angle of the mandible and the onset of the brisk, angular movement of the hyoid.
5. Determine whether there is a relation between bolus head location and Penetration–Aspiration Scale scores.

Method

Participants

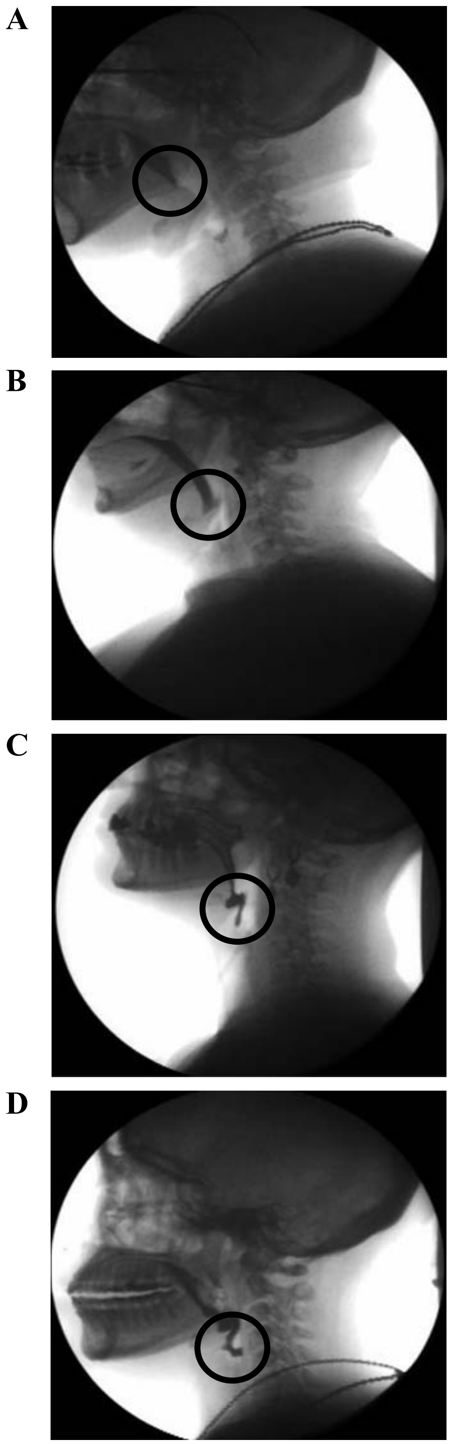
The study protocol was submitted for full review and was approved by the Institutional Review Board at the Medical University of South Carolina. Eighty-two healthy, human volunteers gave written, informed consent. These volunteers were recruited to represent a uniform distribution of ages along the aging continuum. Medical and surgical history and medications were obtained via patient interview and written survey. Volunteers with histories of the following upper aerodigestive tract surgeries were excluded from study participation: oral, nasal, pharyngeal (including uvulopalatopharyngoplasty), laryngeal, and esophageal resections. Exclusion criteria also included known history of swallowing disorders, dysphagia, hiatal hernia, chronic indigestion, gastroesophageal reflux disease, pulmonary disease, cancer of the head and neck, neurological disease, current medications with known effects on swallowing or breathing, and tobacco use during the past 10 years. Patients were not excluded if they had a history of tonsillectomy, adenoidectomy, or sinus surgery. All participants were eating solid foods and drinking liquids as part of a regular diet and presented with no swallowing complaints at the time of study.

Data collection. Participants were recruited on a voluntary basis by flyer and newspaper advertisement. Swallowing physiology was measured using digital videofluoroscopy. All Modified Barium Swallow Studies were conducted by certified speech-language pathologists with a radiologist present and were recorded on a digital, synchronous, dual-modality video-recording device with high temporal resolution (Digital Swallowing Workstation Model 7200, Kay Elemetrics). The fluoroscopic unit (Siemens Sireskop) was equipped with a 1024-line video system. Nasal respiratory airflow was captured using a standard 7-ft nasal cannula coupled to the workstation using the Swallowing Signals Lab hardware and software to create a digital display of the respiratory phase and the *swallow-related apnea duration,* operationally defined as the period of nasal airflow cessation during swallowing (Martin-Harris et al., 2003; Martin-Harris, Brodsky, et al., 2005; Martin-Harris, Michel, & Castell, 2005). The nasal cannula was calibrated immediately prior to the study of each participant.

The sampling rate for the respiratory tracing was 250 Hz. This was considered an acceptable sampling rate for detecting breathing that occurs an average of 10–12 times per min in adults (Berne & Levy, 1998). The hardware and software used for digital data capture and analysis allowed for a doubling of the resolution (or number of images captured) relative to standard VHS recordings. The 30 video frames per second in VHS format are equivalent to twice that in this digital analysis, or 60 video fields per second. This improved sensitivity of measurement from approximately 33.3 ms in VHS format to approximately 16.7 ms per video field. Testing was conducted in a standard fluoroscopy suite. Coning of the x-ray beam limited radiation exposure to the superior structures of the aerodigestive tract. The field of view was delimited anteriorly by the lips, superiorly by the nasal cavity, posteriorly by the posterior pharyngeal wall, and inferiorly by the pharyngoesophageal segment (i.e., C_5–C_6; Logemann, 1983, 1997). Participants were positioned in the lateral viewing plane while standing, and they self-administered two discrete trials of 5-ml liquid boluses of barium sulfate contrast solution (Liquid Barosperse Barium Sulfate Suspension, Lafayette Pharmaceuticals) per graded medicine cup. We chose this conservative volume to simulate a safe bolus size that is typically administered to patients with dysphagia during a videofluoroscopic examination (Logemann, 1983, 1997) and that is easily swallowed in one attempt. Volunteers were instructed to drink the liquid in their usual manner. No additional instruction (e.g., changes in timing, manner of swallowing) was given because our aim was to analyze natural liquid swallowing behavior. The fluoroscope was activated by the radiologist during the participant's self-administration of the contrast material into the oral cavity and remained activated until the bolus tail entered the esophagus through the pharyngoesophageal segment. Radiation exposure times were 1 min or less for all participants.

Measurement. All measurements were conducted by the first author with two independent observers present for agreement. The video field at the onset of the distinguishable and brisk, angular motion of the hyoid (Ishida, Palmer, & Hiiemae, 2002) marked the onset of the pharyngeal swallow and determined the categorical bolus head location. Based on our previous work (Martin-Harris et al., 1999, 2003; Martin-Harris, Brodsky, et al., 2005; Martin-Harris, Michel, & Castell, 2005), an acceptable error rate was established as two video fields, or approximately 34 ms. Location of the bolus was defined a priori using four categorical variables. These variables were based on the location of the head of the bolus, or *leading edge,* relative to an anatomical radiographic marker. These markers were as follows: (a) bolus head anterior to or at the posterior angle of the mandible, (b) bolus head at the vallecular pits, (c) bolus head in the hypopharynx superior to the pyriform sinuses, and (d) bolus head to the pyriform sinuses (see Figure 1). Additionally, we analyzed the onset of swallow-related apnea using nasal respiratory airflow. The rationale for this respiratory–swallow recording method has been previously described (Martin-Harris et al., 2003; Martin-Harris, Brodsky, et al., 2005; Martin-Harris, Michel, & Castell, 2005; Tarrant, Ellis, Flack, & Selley, 1997). This measurement was defined on the basis of the signal recorded by the workstation using the Swallowing Signals Lab hardware and software. The onset of swallow-related apnea, therefore,

Figure 1. Categories of bolus location at the initiation of brisk hyoid movement signaling initiation of the pharyngeal swallow. (A) Bolus head at posterior angle of the mandible. (B) Bolus head at vallecular pits. (C) Bolus head in the hypopharynx superior to the pyriform sinuses. (D) Bolus head to pyriform sinuses.



was considered to be the beginning of the plateau in the respiratory trace along the abscissa (see Figure 2).

The presence of *airway penetration* (i.e., entry of contrast into the laryngeal vestibule) and *aspiration* (i.e., entry of contrast below the level of the true vocal folds; Logemann, 1983, 1997) was also recorded for each swallow using the standardized Penetration–Aspiration Scale (PA Scale; Robbins, Coyle, Rosenbek, Roecker, & Wood, 1999; Rosenbek, Robbins, Roecker, Coyle, & Wood, 1996). The PA Scale is an 8-point, multidimensional indicator of airway invasion that describes (a) whether the airway is invaded; (b) if so, to what level of airway invasion relative to the vocal folds; (c) the participant's response to the airway invasion; and (d) whether the invasive material is ejected from the airway (see Table 1).

Results

Seventy-six volunteers were included in the study, with ages ranging from 21 to 97 years (M = 58.7 years; SD = 23.0). The age distribution of the study sample is given in Figure 3. All attempts to swallow the liquid from the cup were completed in one swallow. Volunteers who were not able to accurately follow test instructions (n = 2) and those with temporal measures that indicated extreme outliers (n = 4) were excluded from the analyses. These exclusions were individually investigated. The 2 participants who did not follow the instructions moved their head and body position on each swallow and limited the visual field for accurate analysis. Four participants initiated apnea onset and/or apnea offset over 3 *SD*s above the mean value for the entire sample, thus indicating that these represented atypical participants. These participants who held their breath longer were possibly swallowing atypically under the laboratory conditions. In this size sample, these extreme outliers inflated the estimates of central tendency and variance and would have biased the results. Seventy-six participants were included in the final analyses. The study sample was balanced for gender and ethnicity.

Timing of bolus head arrival at the posterior angle of the mandible and initiation of the pharyngeal swallow. The time of bolus head arrival at the posterior angle of the mandible and the time of onset of the brisk hyoid motion were different. Eighty percent of the participants demonstrated initiation of hyoid motion after bolus head arrival on at least one trial, and 49% of participants did so on both swallow trials (see Figure 4). Paired t tests for Trials 1 and 2 demonstrated that the difference in timing of bolus arrival and onset of hyoid motion was significant for both trials: Trial 1, $t(75) = 3.178, p = .002$; Trial 2, $t(75) = 4.974$, $p < .0005$. The overlapping 95% confidence intervals for Trial 1 (34, 148) and Trial 2 (78, 183), with positive numbers representing hyoid motion after the bolus arrives

Figure 2. Screenshot of simultaneous videofluoroscopy and respiratory trace data.

at the posterior angle of the mandible (i.e., delay), were not significantly different ($p > .05$).

Age relative to bolus head arrival and bolus location at the initiation of the pharyngeal swallow. The relation of age and bolus location at the onset of hyoid motion is depicted in Figure 5. Onset of hyoid movement relative to arrival of the bolus at the posterior angle of the mandible was longer in older participants (>50 years) in both trials. Variability, however, was observed at all ages.

Swallow-related apnea and initiation of the pharyngeal swallow. Paired comparisons showed a difference in the times of apnea onset and onset of hyoid motion: Trial 1,

Table 1. Scoring system for the Penetration–Aspiration Scale.

Score	Description
1	Contrast does not enter airway
	Penetration
2	Contrast enters the airway, remains above the vocal folds, no residue
3	Contrast remains above vocal folds, visible residue remains
4	Contrast contacts vocal folds, no residue
5	Contrast contacts vocal folds, visible residue remains
	Aspiration
6	Contrast passes through glottis, no subglottic residue visible
7	Contrast passes through glottis, visible subglottic residue despite patient's response
8	Contrast passes through glottis, visible subglottic residue, no patient response

Figure 3. Participant age distribution.

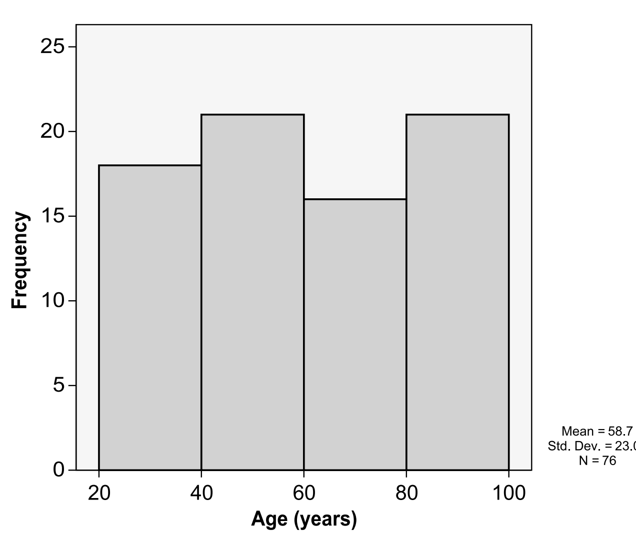
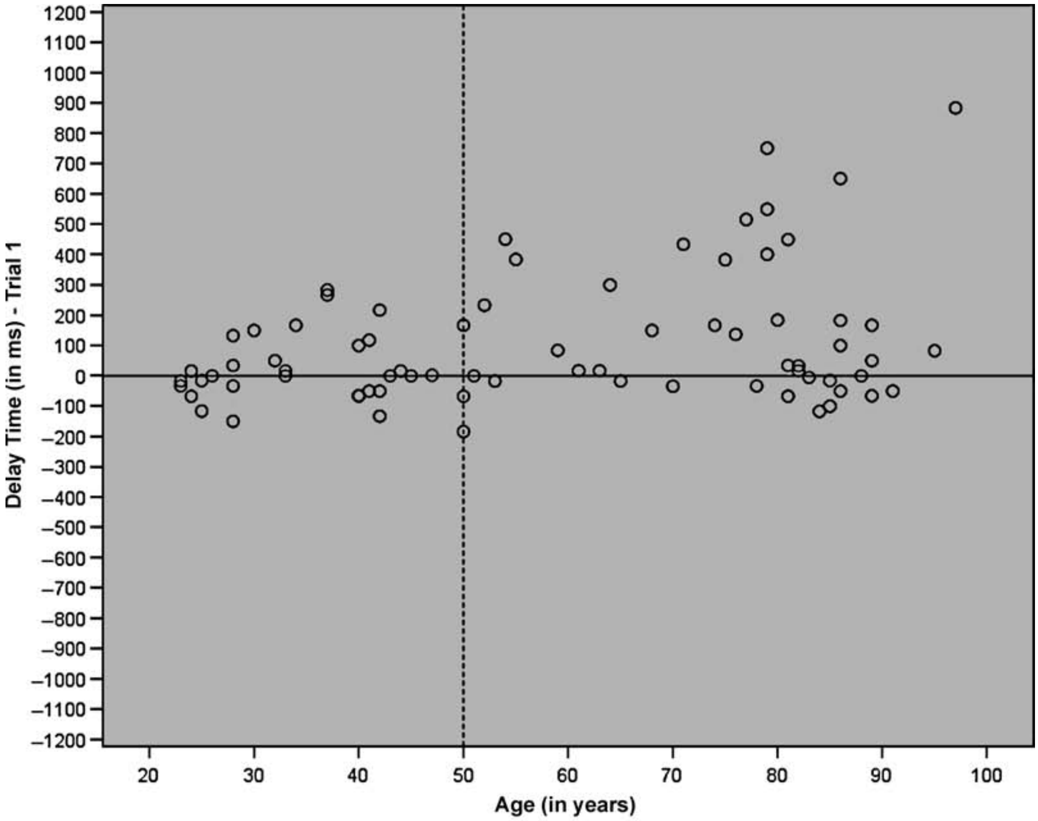


Figure 4. Distribution of age relative to delayed initiation of the pharyngeal swallow.



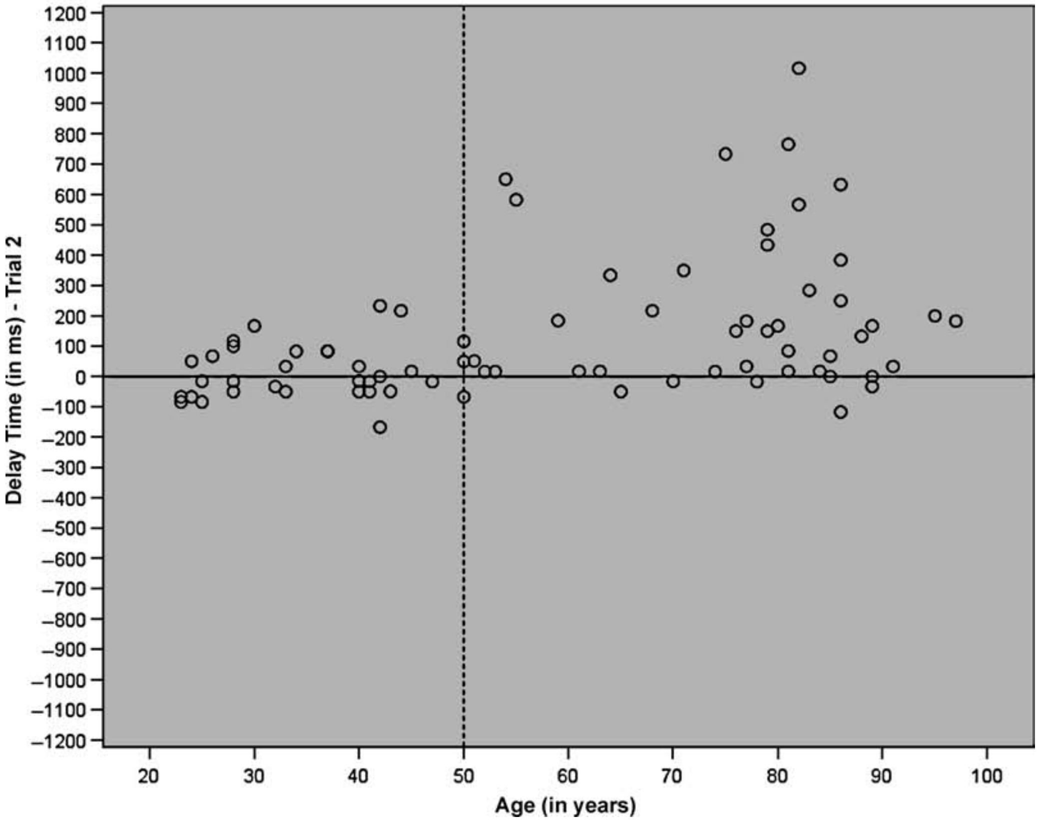
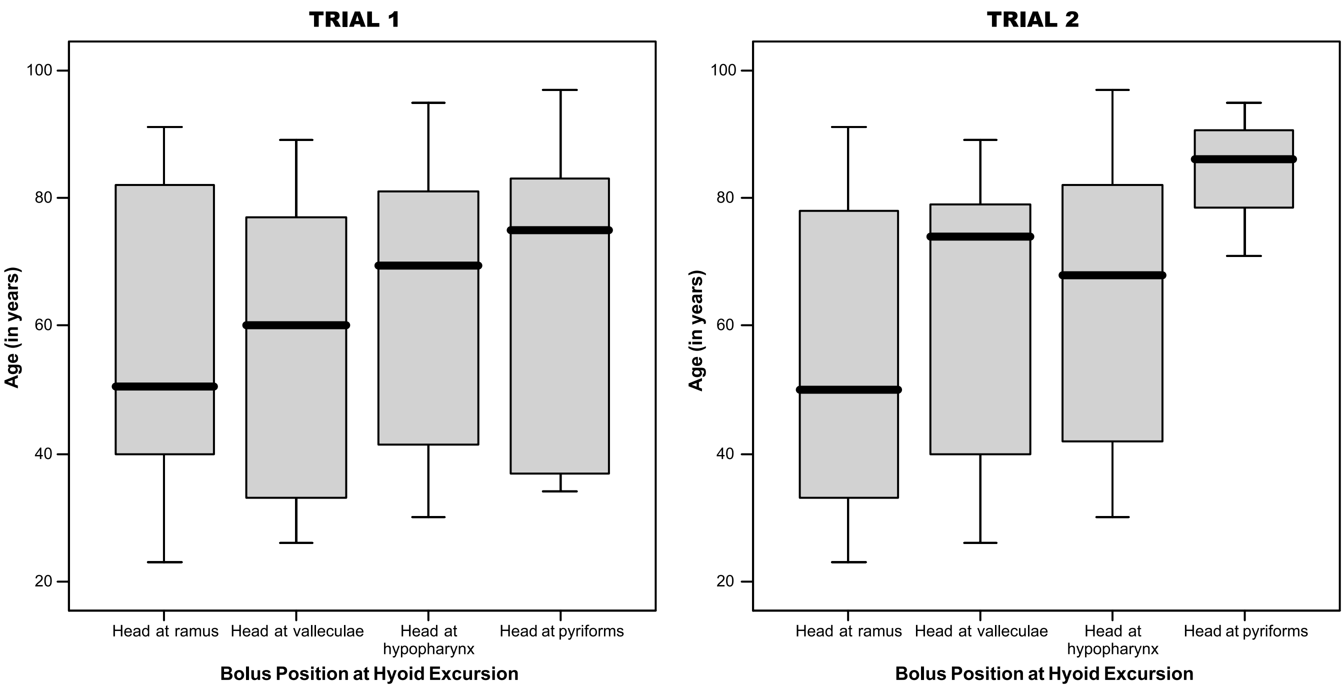


Figure 5. Plots of median age relative to bolus location at the time of hyoid excursion in Trials 1 and 2. Bars represent extreme values. Horizontal lines at either end of a vertical line represent the highest number in the set and the lowest number in the set.



$t(75) = 5.643, p < .0005$; Trial 2, $t(75) = 4.966, p < .0005$. All participants initiated apnea prior to the onset of hyoid motion. Apnea onset was highly variable and ranged from 16.7 ms to 7.33 s prior to the onset of hyoid motion.

Swallow-related apnea and bolus head location. In addition to examining the onset of apnea with onset of hyoid motion, we were also interested in describing the relation between the onset of apnea and bolus head location at the initiation of the pharyngeal swallow. Swallow-related apnea began with the bolus head location either anterior to or at the posterior angle of the mandible in 63 individuals (83%) in Trial 1 and in 56 individuals (74%) in Trial 2. Thirteen participants (17%) in Trial 1 and 20 participants (26%) in Trial 2 did not begin apnea until the bolus reached the valleculae. All participants initiated swallow-related apnea prior to bolus head arrival in the hypopharynx.

PA Scale scores. We used the PA Scale (Robbins et al., 1999; Rosenbek et al., 1996) to determine the relation of the presence and depth of penetration and aspiration to the onset of hyoid motion and bolus head location at the onset of hyoid motion. Of the 43 participants who demonstrated onset of hyoid movement after bolus head arrival at the posterior angle of the mandible (i.e., delay), 39 participants (91%) in Trial 1 and 44 of 51 participants (86%) in Trial 2 were scored a 1 (i.e., contrast does not enter airway) on the PA Scale. Two of 43 delayed participants (5%) in Trial 1 and 6 of 51 delayed participants (12%) in Trial 2 were scored a 2 (i.e., contrast enters the airway, remains above the vocal folds, no residue) on the PA Scale. One delayed participant in Trial 1 and 1 in Trial 2 were scored a 3 (i.e., entered the airway above the vocal folds but was not ejected). Finally, 1 delayed participant in Trial 1 was scored a 6 (i.e., entered the airway below the vocal folds and was ejected).

Discussion

This study was designed, first, to clarify the relation between the time of bolus head arrival at the posterior angle of the mandible; the onset of the brisk, angular movement of the hyoid; and the onset of swallow-related apnea. Second, we sought to determine the bolus head location at the onset of hyoid motion (i.e., initiation of the pharyngeal swallow). Finally, these factors were then related to aging and PA Scale scores.

It should be highlighted to the reader that interpretation of our hyoid measures was consistent with that described by Palmer et al. (2002). The initial movement of the hyoid associated with stabilization of the floor of the mouth was not included in our analysis. Rather, we measured the onset of the brisk, angular (superior and anterior) movement of the hyoid to indicate the onset of the pharyngeal swallow events—soft palate elevation and retraction, progression of supra- and intrinsic laryngeal valving, pharyngoesophageal segment opening, tongue base retraction, and pharyngeal contraction (Logemann, 1983, 1997).

Using the operational definition of a *delayed pharyngeal swallow* as a temporal difference between the bolus head arrival at the posterior angle of the mandible and the onset of hyoid motion with the onset of hyoid motion occurring later (Logemann, 1983, 1997; Robbins et al., 1992), the majority of our study sample that included healthy individuals without complaints or histories of swallowing difficulty would be classified as having a delayed initiation of their pharyngeal swallow on at least one trial. Forty-three percent (Trial 1) and 33% (Trial 2) were observed with the bolus (5-ml liquid) head at the posterior angle of the mandible after hyoid movement (i.e., hyoid movement occurred prior to the arrival of the bolus at posterior angle of the mandible)—a timely swallow by earlier descriptions. Participants who exhibited delay, however, began hyoid movement an average of 222 ms and 216 ms in Trial 1 and Trial 2, respectively, after the bolus reached the posterior angle of the mandible (i.e., more than 7 video frames or 15 video fields; see Figure 4). Although a delayed swallow was observed across the age spectrum in this study, a trend showed that healthy individuals over the age of 50 years have longer delays than do younger individuals. Our results—in part—agree with previous studies of the aging population (Linden, Tippett, Johnston, Siebens, & French, 1989; Logemann et al., 2000; Rademaker, Pauloski, Colangelo, & Logemann, 1998). The work by Kendall and Leonard (2001); Robbins et al. (1992); Sonies, Parent, Morrish, and Baum (1988); and Tracy et al. (1989) demonstrated that the onset of hyoid motion relative to bolus head arrival at the posterior angle of the mandible is later as individuals age.

We extended the temporal indicators used to signal the onset of the pharyngeal swallow by using a clinically practical and meaningful descriptor of "pharyngeal delay" using four categories to describe bolus head location at the onset of hyoid movement. Using this method, the majority of participants demonstrated that the bolus head was in position at the posterior angle of the mandible at the onset of hyoid movement in the younger groups. There was, however, one 91-year-old who demonstrated this "timely and safe" position relative to the onset of the swallow. More than 25% of our sample exhibited a bolus head location in the vallecular pits at the onset of hyoid motion. The youngest of these was 26 years old, and the oldest was 89 years old. Thirteen of our participants demonstrated a bolus head location in the hypopharynx superior to the pyriform sinuses at the onset of the pharyngeal swallow. This position was represented by the young (the youngest individual in our sample was 26 years of age) and the old (the oldest individual in our sample was 97 years of age). Finally, 5 participants demonstrated a bolus head location in the pyriform sinuses at the onset of the pharyngeal swallow. None of these individuals were younger than 50 years of age. Although a trend was demonstrated between aging and a more distal bolus head location, our data support that a more advanced pharyngeal bolus head location is certainly a phenomenon demonstrated in very young adults, the exception being the pyriform sinus location.

Regardless of a delay in the onset of hyoid excursion relative to bolus head location, our data showed that 97% of participants in Trial 1 and 100% of participants in Trial 2 scored 1–3. The spread of PA Scale scores in our group of 76 healthy adults ranged from 1 to 3 in Trial 1 and 1 to 6 in Trial 2. These results agree with Robbins et al. (1999), who suggested that healthy individuals will score 1 or 2 on the PA Scale, and Rosenbek et al. (1996), who stated that scores as high as a 3 were found to be normal in older individuals. The only "nonnormal" score (i.e., scores 4–8) was one 41 year-old woman who scored a 6 (i.e., the bolus entered the airway above the vocal folds but was not ejected) on the first of the two 5-ml liquid bolus trials. Her subsequent trial of a 5-ml liquid bolus showed no airway invasion and was scored a 1. These observations speak to the potentially wide intraparticipant variability that can be seen across repeated swallows.

Variability was also observed in the onset of swallow apnea and the onset of the pharyngeal swallow (i.e., hyoid motion). The cessation of breathing during the pharyngeal swallow is critical to airway protection. To our knowledge, this article is the first that relates the onset of swallow-related apnea to the structural movements signaling the onset of pharyngeal swallow initiation. Our previous work using 5-ml cup-drinking swallows showed that the onset of apnea relative to the onset of oral bolus transport was highly variable across young and old adults. In the current study, we found similar variability in the onset of apnea relative to the onset of hyoid motion. The majority of individuals, however, initiated apnea well in advance of bolus head arrival at the posterior angle of the mandible, and no participant initiated apnea later than bolus arrival at the valleculae. There was a trend observed for apnea onset occurring later in the older participants when the bolus advanced to the valleculae. However, the range of variation and the sample size do not allow for any conclusions to be drawn from this finding. If future studies with larger numbers of participants were to find that older adults do initiate apnea later, this finding, combined with our previous findings of greater occurrence of inhalation versus exhalation surrounding the swallow in older controls (Martin-Harris, Brodsky, et al., 2005), may be a signal that predisposes older individuals to penetration just prior to pharyngeal swallow initiation. Certainly, the consequences of apnea initiation well after the onset of the pharyngeal swallow would pose a likely and severe threat for aspiration. Future studies of patient populations may elucidate the clinical relevance of these findings when combined with physiologic swallowing impairments.

Clinicians should understand that a delayed initiation of the pharyngeal swallow, indicated by an advanced bolus head location in the mid- or distal pharynx at the onset of hyoid motion, may not be an indicator of oropharyngeal swallowing impairment when all other physiologic components of the swallow are functioning safely and efficiently. Rarely does a patient present with such a focal physiologic swallowing impairment. The oropharyngeal swallow represents a synergy of overlapping and interdependent events that propel the bolus through the oropharyngeal cavities, close the valves critical for airway protection, and open the valves necessary for bolus entry into the esophagus (Martin-Harris, Michel, & Castell, 2005). Overreporting normal variants in the timing of individual swallow components can be misleading and confusing to referring physicians, patients, and caregivers, and may be of no functional significance. Certainly extreme diet modifications, such as thickened liquids, typically are not warranted in such cases. Rather, swallowing analyses should include multivariate tests capable of analyzing the contribution of combinations of swallowing components to the overall swallowing impairment and outcome.

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