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# Factors Influencing Bolus Dwell Times in Healthy Older Adults Assessed Endoscopically

**Susan G. Butler, PhD**[1], **Jonathan Maslan, BS**[1], **Andrew Stuart, PhD**[2], **Xiaoyan Leng, PhD**[3], **Erika Wilhelm**[1], **Catherine Rees Lintzenich, MD**[1], **Jeff Williamson, MD**[4], and **Stephen B. Kritchevsky, PhD**[4]

[1]Department of Otolaryngology, Wake Forest University School of Medicine Winston-Salem, NC 27157 USA

[2]Department of Communication Sciences and Disorders, East Carolina University Greenville, NC 27858 USA

[3]Department of Biostatistical Sciences, Wake Forest University School of Medicine Winston-Salem, NC 27157 USA

[4]Department of Internal Medicine, Wake Forest University School of Medicine Winston-Salem, NC 27157 USA

## Abstract

**Objectives/Hypothesis—**Scant data exist on normal bolus dwell time assessed during Flexible Endoscopic Evaluation of Swallowing (FEES). The purpose of this study was to examine bolus dwell time in healthy older adults. Since it has been previously reported that some healthy older adults aspirate, we also sought to determine if bolus dwell time varied as function of aspiration status.

**Study Design—**Prospective

**Methods—**Seventy-six healthy volunteers from the 7th, 8th, and 9th decades of life participated. Dwell times were analyzed via FEES as a function of pharyngeal location, liquid type, delivery method, purée type, viscosity, age, and gender.

**Results—**Longer dwell times were evidenced with the eldest participants, straw delivery, and the smallest volume. Adults in the 9th decade were 4.8 ($p = 0.01$) and 3.8 ($p = 0.02$) times more likely to have longer dwell times at the vallecula and 7.1 ($p = 0.002$) and 3.8 ($p = 0.02$) at the pyriform sinus than those in the 7th and 8th decades, respectively. Longer dwell times at the vallecula and pyriform sinuses were 2 and 2.38 times ($p < 0.0001$) more likely for straw than cup delivery, respectively. Five ml boluses were 1.5 times ($p < 0.05$) more likely to result in longer dwell times than larger volumes. Bolus dwell times did not significantly differ as a function of aspiration status.

**Conclusions—**Advanced age, straw delivery, and small volumes yielded longer dwell times. These variables should be considered before diagnosing an abnormal bolus dwell time in elder patients.

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Send Proofs and Reprint Requests to: Susan G. Butler, PhD, CCC-SLP, BRS-S Associate Professor Wake Forest School of Medicine Department of Otolaryngology Medical Center Boulevard Winston-Salem, NC 27157 sbutler@wfubmc.edu Office: (336) 716-7272 Fax: (336) 716-3857.

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**Keywords**

pharyngeal response; bolus dwell times; swallow; older adults; endoscopic; FEES

## Introduction

Older adults do not swallow as efficiently as younger adults. Nevertheless, the normal spectrum of swallowing physiology in older adults has yet to be fully elucidated, specifically in bolus transit before onset of the pharyngeal swallow. The functional differences between normal variability and dysphagia are relevant, since swallowing dysfunction, specifically increased bolus dwell time, can predispose to aspiration (1) and its associated complications. While aspiration is more common in older adults with compromised sensorimotor function, Butler and colleagues (2, 3) have recently shown that some healthy older adults exhibit occasional trace, silent aspiration of liquids when examined under flexible endoscopic evaluation of swallowing (FEES). Determining which factors impact bolus dwell time and aspiration in healthy older adults is necessary to characterize normal and pathological swallowing physiology in these individuals.

It has been purported the pharyngeal phase of swallowing begins when the brisk, angular motion of the hyoid bone occurs. Bolus dwell time, a term often used for videoendoscopic evaluations of swallowing, refers to bolus hesitation in the pharynx before onset of the pharyngeal swallow. Physiologically, it is similar to videofluoroscopic measures of “pharyngeal delay time” and “stage transition time” (i.e., the time it takes for the bolus to pass the ramus of the mandible until the onset of hyolaryngeal excursion). Prolonged bolus dwell time could theoretically lead to greater aspiration risk, as it increases bolus exposure in and around the laryngeal vestibule.

Over the past thirty years, understanding of normal bolus location during the pharyngeal swallow and the components that comprise a delayed swallow has evolved substantially. Historically, bolus passage beyond the anterior faucial arch that did not trigger the swallow reflex was defined as abnormal. Further, a “delayed swallow” was defined as the bolus persisting in the vallecula or passing beyond the tongue base before the pharyngeal swallow. More recent studies have suggested that bolus passage beyond these landmarks also may be normal. Studies in healthy individuals have demonstrated bolus entry into the pharynx before pharyngeal swallowing (4-10), implying that this phenomenon does not denote delayed swallowing or pathology. Dua (7) demonstrated endoscopically in the majority of healthy young adults that liquid and solid boluses enter into both the vallecula and pyriform sinuses before the onset of swallowing. Stephen (11) demonstrated that the timing of the bolus head arrival at the posterior angle of the mandible varied relative to time of hyolaryngeal excursion, at times preceding it, at times following it. The steps involved in normal deglutition have been well studied, but insufficient data are available regarding factors that affect bolus dwell times before the pharyngeal swallow.

Intuitively, one would contemplate that various factors (e.g., delivery method, bolus volume, and liquid type) would affect bolus dwell time. Very few researchers have, however, examined these factors. Larger bolus volumes may elicit longer bolus dwell times compared to small bolus volumes considering a trend seen with videofluoroscopic measures of stage transition duration (12). Bolus type also may have a substantial bearing on bolus dwell time: Dua and colleagues found more solids than liquids entered the pharynx before initiation of the swallow (7). Although bolus dwell time was not reported, aspiration risk was increased as a function of liquid type (i.e., milk showing a greater incidence of penetration and aspiration than water (3)). Moreover, aspiration risk increased as a function of fat content, with skim milk showing the least aspiration, and 2% and whole milk showing the highest incidence. If bolus dwell time is indeed a surrogate marker for aspiration risk as previously proposed, it is important to clarify whether changes in liquid type affect this measure.

Traditionally, bolus transit within the oral cavity and pharynx has been evaluated with videofluoroscopy using barium contrast, which provides a lateral view as the bolus courses through the gastrointestinal tract. Limited studies have examined pharyngeal response endoscopically. While FEES does visualize some of the same anatomy identified during videofluoroscopy, it allows a direct view of bolus flow through the pharynx, as well as the vallecula, pyriform sinuses, laryngeal vestibule, vocal folds, and trachea without the need for contrast or radiographic exposure. Therefore, using FEES, the vallecula and pyriform sinuses can be visualized and the entry of bolus into these areas precisely measured before the pharyngeal swallow. Additionally, FEES has a similar or increased sensitivity in detecting aspiration and is universally used for swallowing evaluations.

Ultimately, relevant normative data on bolus dwell times will need to include differences in liquid type, viscosity, volume, and mode of bolus consumption. We conducted this FEES study to determine bolus dwell time in healthy older adults as a function of pharyngeal location (i.e., pyriform sinuses, vallecula), liquid type (i.e., water; skim, 2%, whole, and soy milk), delivery method (i.e., cup vs. straw), purée type (i.e., applesauce vs. pudding), viscosity (i.e., liquid, purée, and solid), age, and gender.

## Method

### Participants

Seventy-six community-dwelling adults participated (see Table 1). Eighteen participants were 61-70 years old (*M* = 65.9 years, *SD* = 1.9), 26 were 71-80 years old (*M* = 77.4 years, *SD* = 1.9), and 33 were 81-90 years old (*M* = 83.6 years, *SD* = 2.4). Participants were ambulatory and reported good health. In addition, participants reported no history of swallowing, speech, and voice problems; or known neurologic or otolaryngologic disorders. Participants were recruited by bulletins approved by the Wake Forest University Health Sciences Institutional Review Board. Informed consent was obtained prior to participation.

### Procedure

A KayPENTAX Swallowing Workstation (KayPENTAX, Inc., Lincoln Park, NJ) was utilized for the endoscopic swallowing examinations, as described previously (2, 3, 13). Participants underwent FEES while sitting in the upright position. A 3.1 mm digital flexible endoscope was lubricated with Surgilube® (Altana Inc., Melville, NY) and passed transnasally, typically on the floor of the nose, by the first author to obtain a superior view of the hypopharynx. The endoscope was maintained at swallowing position before initiation of the swallow. Swallowing position required that the distal end of the endoscope be just above the top of the epiglottis so that the entire base of tongue, vallecula, the tip of the epiglottis, posterior pharyngeal wall, lateral pharyngeal walls (e.g., lateral channels), and laryngeal vestibule were visualized before bolus administration.

Each participant contributed 41 swallows for determination of bolus dwell times. These included 36 different liquid boluses (i.e., 4 liquids [water; skim, 2%, and whole milk] × 4 volumes [5, 10, 15, and 20 ml] × 2 delivery methods [cup vs. straw]) plus soy milk × 4 volumes [5, 10, 15, and 20 ml] × 1 delivery method [straw]), 4 purée boluses (i.e., 2 purées [applesauce vs. pudding] × 2 volumes [5 and 10 ml]), and 1 solid bolus (i.e., 2 g of graham cracker). All boluses were taken from the refrigerator simultaneously approximately 5-10 minutes prior to administration, and were dyed with green food coloring to improve endoscopic visualization. Approximately 0.3 ml of green food coloring was added per 118 ml liquid. The boluses were randomly presented to each participant in one data collection session of approximately 15 minutes. Pre-measured liquid boluses were placed in 30 ml plastic cups for the cup delivery conditions. For straw administrations, a straw 185 mm in length with an inner diameter of 4.6 mm was placed in a 118 ml cone shaped cup (Solo Cup Company, Urbana, IL). Participants were instructed, before bolus administration, that once handed a cup they should swallow all liquid in one swallow when ready (14); however, they could take more than one swallow if needed.

Swallows were reviewed in real-time, slow motion, and frame-by-frame to assign the corresponding bolus dwell times at the vallecula and pyriform sinuses in accordance with previously published methods (7, 13). The first author reviewed the swallows approximately 1 month after the initial recording and was blinded to the participant, but not the bolus type, delivery method, or bolus volume. Bolus dwell time was measured in seconds from the first frame of bolus head approximation to the vallecula and/or the pyriform sinus(es) until the first frame of complete obscured image. Obscured image (i.e., whiteout) during FEES occurs when the oropharyngeal mucosa enclose the distal end of the endoscope, and is an estimate of the pharyngeal stage of the swallow. In a simultaneous endoscopic and fluoroscopic study, Logemann and colleagues (15) demonstrated the onset of hyoid elevation (indicating the onset of the pharyngeal phase of the swallow), measured fluoroscopically, occurs only 0.06 seconds before [measured from Figure 1 in Logemann paper] onset of the obscured image (15). Thus, onset of the obscured image is used as an endoscopic surrogate measure for onset of the pharyngeal phase of swallow.

Most often, the obscured image consisted of a complete whiteout. However, frames sometimes included small segments of green, likely due to parts of the green bolus that did not clear from the distal tip of the endoscope. In a few instances, small portions of pharyngeal mucosa or darkened segments could still be visualized within the white and/or green screen; thus, a judgment was made as to the appropriate first frame of a completely obscured image. In instances when the swallow started before bolus head approximation to the vallecula and/or pyriform sinuses, a zero value was assigned to the bolus dwell time. In addition, occasionally participants would take a second swallow to empty the premeasured bolus volume from the cup. In these situations, the original/first bolus swallow was used to acquire the bolus dwell time measures.

## Potential Confounders

Potential confounders of previous intubation, lung disease (e.g., Chronic Obstructive Pulmonary Disease, emphysema), previous treatment for cancer, and number of medications were assessed relative to aspiration status and found to be insignificant ($p > 0.05$).

## Data Analysis

A total of 6,232 data points were available for statistical analyses (i.e., 76 participants × 41 swallows at both the vallecula and pyriform sinuses). Many participants had a "zero" bolus dwell time; therefore, a mixed-distribution model was used to model such data. In general, mixed-distribution models deal with positive outcomes (i.e., $\geq 0$, as for bolus dwell time), repeated measures within the same subject (as in our study), and excessive zeros in response variables. The model had two parts. The first part was a logistic model to estimate the probability of a positive bolus dwell time versus "zero." The second part modeled time when the bolus dwell time response met the criteria of being greater than zero. For the analyses at the pyriform sinus location, we could only calculate data for the first experimental question: all but two data points were zeros, which comprised the second and third experimental questions. For the various regression models, age group, gender, aspiration status, liquid type, puree type, bolus volume, bolus viscosity, and delivery method served as the independent variables while bolus dwell time served as the dependent variable, either binary in the first part, or continuous in the second part. SAS version 9.1 was used for all analyses and an $\alpha$ level of 0.05 was set as statistically significant.

### Reliability

To acquire inter-rater reliability, a second rater; blinded to the participants and original bolus dwell times; assigned bolus dwell times to 220/3344 study swallows. That is, the 44 swallows of five randomly identified participants were subjected to the analyses thus encompassing all bolus types, delivery methods, and volumes. The second rater, like the first; was not blinded to bolus type, delivery method, or volume. Since most response times were zeros, outcomes were coded as 1 (above 1) or 0 (zero) and calculated overall agreement rates, which were 73.7%. for the vallecula and 86.6% for the pyriform sinuses.

## Results

### Vallecula

**Does Bolus Dwell Time Vary as a Function of Aspiration Status, Age Group, Gender, Liquid Type, Bolus Volume and Delivery Method?—**Bolus dwell time at the vallecula differed significantly for delivery method, bolus volume, and age group (Table 2). In general, straw delivery, small bolus volumes, and advanced age elicited the longest bolus dwell times at the vallecula. Specifically, straw delivery was two times more likely than cup delivery to have a greater than zero dwell time ($p < 0.0001$). For those who had a greater than zero bolus dwell time: On average, straw delivery elicited a 0.19 greater dwell time ($p = 0.0002$). Five ml bolus volumes were 1.5 ($p = 0.0162$), 1.6 ($p = 0.0040$), and 1.6 ($p = 0.0038$) times more likely than 10, 15, and 20 ml volumes, respectively, to have a bolus dwell time greater than zero. Likewise, those in the 9th decade of life were 4.8 ($p = 0.0113$) and 3.8 ($p = 0.0154$) times more likely to have a bolus dwell time greater than zero compared to those in the 7th and 8th decades, respectively. Adults in the 9th decade of life demonstrated a 0.42 increased dwell time ($p = 0.0049$) compared to adults in the 7th decade of life, once the bolus dwell time was greater than zero. The effects of liquid type, gender, and aspiration status were not significant ($p > 0.05$).

**Does Bolus Dwell Time Vary as a Function of Aspiration Status, Age Group, Gender, Purée Type, and Bolus Volume?—**Adults in the 9th decade of life were 9.8 times more likely to have a bolus dwell time greater than zero ($p = 0.0323$), and pudding boluses elicited a 0.39 second greater dwell time ($p = 0.0046$) compared to applesauce (Table 3). The main effects of purée bolus type, gender, and aspiration status were not significant ($p > 0.05$).

**Does Bolus Dwell Time Vary as a Function of Aspiration Status, Age Group, Gender, and Viscosity?—**Viscosity did not increase the risk of having a bolus dwell time greater than zero (Table 4). However, in general, the more viscous the bolus, the longer the bolus dwell time at the vallecula. Specifically, dwell times for cracker and pudding boluses were 1.16 ($p = 0.0000$) and 0.98 ($p = 0.0001$) seconds longer, respectively, compared to 2% milk. Likewise, dwell times for cracker and applesauce boluses were 1.21 ($p = 0.0000$) and 0.72 ($p = 0.0067$) seconds longer, respectively, compared to water. In addition, bolus dwell times for water, applesauce, and cracker for adults in the 9th decade of life was 0.51 seconds longer compared to adults in the 8th decade of life ($p = 0.0400$) once the bolus dwell time was greater than zero. The effects of aspiration status and gender were not significant ($p > 0.05$).

### Pyriform Sinuses

**Does Bolus Dwell Time Vary as a Function of Aspiration Status, Age Group, Gender, Liquid Type, Bolus Volume and Delivery Method?—**Bolus dwell time at the pyriform sinuses differed significantly for delivery method, bolus volume, and age group (Table 5). In general, straw delivery, small bolus volumes, and advanced age increased risk of a bolus dwell time greater than zero at the pyriform sinuses. Specifically, straw delivery was 2.38 times more likely than cup delivery to have a dwell time greater than zero ($p = 0.0000$). Five ml bolus volumes were 1.6 ($p = 0.0249$) and 1.5 ($p = 0.0330$) times more likely than 15 and 20 ml volumes, respectively, to have a dwell time greater than zero. Likewise, adults in the 9th decade of life were 7.1 ($p = 0.0023$) and 3.8 ($p = 0.0155$) times more likely than those in the 7th and 8th decade, respectively, to have a bolus dwell time greater than zero. The effects of liquid type, gender, and aspiration status were not significant ($p > 0.05$).

**Does Bolus Dwell Time Greater Than Zero Or The Duration Of Bolus Dwell Time Predict Aspiration Risk?—**Four of 18 adults in the 7th decade of life, 8 of 26 adults in the 8th decade of life, and 11 of 32 adults in the 9th decade of life showed aspiration. However, there was no significant relationship between aspiration and bolus dwell time at the vallecula or the pyriform sinuses.

## Discussion

Since Logemann published her pivotal work on swallowing in 1983, the concept of a delayed pharyngeal swallow has evolved substantially to widen the spectrum of normal physiological function (5, 7, 16). However, normal function and the risk factors that predispose to variations or delays in the pharyngeal response have not been fully elucidated. In the present study of 76 healthy older adults, it was not uncommon to view boluses entering the vallecula and pyriform sinuses before the initiation of the swallow. Moreover, a bolus dwell time greater than zero in these areas was more likely to occur with straw delivery, small bolus volumes, and advanced age. Additionally, for purées, pudding elicited greater bolus dwell times than applesauce, but there was no significant difference between water and milk. These results contribute to the literature on the wide range of normal bolus dwell times before swallowing initiation, and provide more data on factors affecting bolus dwell time that clinicians and researchers may consider in future efforts.

The pharyngeal phase of swallowing is a complex reflex response. Furthermore, the stimulation of a food or liquid bolus to trigger the pharyngeal phase of swallowing likely depends on stimuli in various receptor fields of the upper aerodigestive tract. Sensory input in swallowing relies on afferent input from cranial nerves IX, X, and the maxillary (V2) and mandibular (V3) divisions of V. The superior laryngeal nerve of cranial nerve X provides the sensory input from the posterior larynx, base of tongue, and hypopharynx. The major trigger for swallowing is likely based on specific patterns and intensity transmitted from receptive fields in the oral cavity, tongue, and pharynx to the swallow centers in the central nervous system. The oral cavity is rich in sensory receptors; however, the innervation associated with the swallowing reflex may be more concentrated in its posterior portions (the tonsils and peritonsillar regions). Additionally, there are many sensory receptors at the junction of naso- and oropharynx, the laryngeal surface of the epiglottis, and the post-cricoarytenoid region. Stimuli such as light touch at the faucial pillars, and water in the hypopharynx and aditus of the larynx, may all be triggers of swallowing. Miller (17) noted in a review that the faucial pillars, preepiglottic sinus (vallecula), glottis, and the base of the epiglottis were the most sensitive areas for triggering swallowing in mammals. Ultimately, it appears the pharyngeal response is dependent on multiple sensory inputs, instead of just one region.

Consistent with the premise that the initiation of the swallow relies on a concert of sensory inputs, we found larger boluses (i.e., 10-, 15-, 20 ml vs. 5 ml) elicited shorter bolus dwell times. Our results and most previous work suggest that the clinical premise, “bigger bolus, better swallow” is better reworded to “bigger bolus, faster swallow”. Ironically, it is typical for many clinicians to start a swallowing evaluation with small bolus volumes in patients with dysphagia, presumably to decrease aspiration risk. If a clinician started with a 5 ml thin liquid bolus volume, identified trace aspiration due to a delay in pharyngeal response (increased bolus dwell time), and failed to proceed further with another trial and/or larger bolus volumes, thin liquids may be recommended inappropriately.

The same rationale may explain why we found straw drinking elicited longer bolus dwell times than cup drinking. Straw drinking, which likely involves smaller bolus volumes than cup drinking (6), may lead to diminished afferent signaling, with increased bolus dwell time before the onset of the swallow reflex. Sequential straw drinking volumes can be variable but average 12 ml (6). Also noteworthy, Daniels (6) found that among healthy young males doing sequential straw drinking, two-thirds of participants consistently did not initiate hyolaryngeal excursion until after the bolus head was inferior to the vallecula. Thus, the straw-mediated bolus trajectory may skip the more anterior portions of the oral cavity. As a result, straw drinking leads not only to a smaller bolus volume, but may also limit the bolus trajectory to a smaller receptive field.

Two main hypotheses may explain the neural drive for the oral and pharyngeal responses of swallowing: (1) as the bolus moves through the mouth and pharynx, it triggers the next step of the swallow response the further it progresses; and (2) once a swallow is triggered, it is a programmed event which does not require further sensory reinforcement to progress. While elements of both may be true, if the pharyngeal response is partially dependent on sequential stimulation, perhaps straw drinking skips some of this early stimulation. Ultimately, more data are needed to substantiate this hypothesis.

The major concern with prolonged bolus dwell times is an increased risk of aspiration, as presumably an open airway is more vulnerable if the bolus approximates the vallecula or the pyriform sinuses. Of clinical interest, however, is that although the etiology for aspiration in healthy older adults is not necessarily the same as in patients with dysphagia, aspiration status was not affected by bolus dwell times in our study. Thus, as suggested in previous work, trace, silent aspiration in healthy older adults may be explained by physiological conditions other than bolus dwell time. We found previously that aspiration status in healthy older adults was correlated with decreased pharyngeal and tongue strength. Larger studies in healthy adults are needed to rule out bolus dwell time as a function of aspiration status and establish whether longer bolus dwell times are indeed associated with aspiration in healthy older adults. Likewise, additional studies, using FEES, are needed to better elucidate the role of bolus dwell time on aspiration in patients, especially given that Perlman (1) found aspiration status was correlated with pharyngeal response greater than 1 second in patients referred for swallowing disorders.

We had expected to find a direct correlation between bolus liquid type and bolus dwell time, since previously both 2% milk and whole milk increased the risk of aspiration by 3.2 and 2.7 fold, respectively, compared with water (3). Nevertheless, we found no significant effect of water versus skim, 2%, and whole milk on bolus dwell time. Shingai (18) has suggested that specific receptors in the laryngopharynx that stimulate swallowing have heightened sensitivity to water compared to other liquids. While such sensitivity might offset a mechanoreceptor effect based on increased viscosity, it would not explain why liquids with increased fat content had a higher incidence of penetration and aspiration, but did not affect bolus dwell time. Also, it is interesting that pudding elicited a 0.39 s greater bolus dwell time than applesauce. This would be consistent with higher viscosity accounting for a longer bolus dwell time, but it is inconsistent with the milk versus water relationship. Ultimately, more studies are necessary to clarify the impact of fat content, bolus type, and viscosity on bolus dwell time, penetration, and aspiration incidence.

Although this is the first study to report increased bolus dwell times as a function of healthy aging as assessed during FEES, our findings of increased bolus dwell times (e.g. pharyngeal swallow delay) with age are consistent with multiple previous videofluoroscopic research studies. This slowing in pharyngeal response or longer bolus dwell time is related to age-associated peripheral and central nervous system changes. Motor performance in older adults, overall, occurs more slowly, likely due to decreased function of neurologic substrates. Thus, the complex effects of aging occurring at vascular, chemical, neural, and muscular levels likely all contribute to longer bolus dwell times relative to the initiation of the swallow.

Although we demonstrate variability in bolus dwell times as a function of age, liquid type, volume, and method of delivery, this variability per se is not pathological. Indeed, older adults have reduced swallowing efficiency in most aspects of deglutition, but are frequently unaware of these changes and are asymptomatic. Asymptomatic silent aspiration and slower swallowing in healthy older adults suggest either that the range of normal swallowing is much broader than previously assumed, or that the phenomenon of subclinical dysphagia is more common than suspected.

In conclusion, this study characterizes normal bolus dwell times in 76 healthy older adults whose swallowing was evaluated via FEES, as a function of age, bolus volume, delivery method, liquid type, viscosity, and aspiration status. These data can serve as benchmark for normal bolus dwell times for use in comparison to patients with dysphagia. Contrary to our hypothesis, aspiration status in this healthy cohort was not associated with bolus dwell times, which may not hold true for larger cohorts of healthy older adults and/or patient populations with dysphagia. Straw drinking, small bolus volume, and advanced age elicited significantly longer bolus dwell times before swallowing initiation, and indicate the need to carefully evaluate the impact of these factors on aspiration status in patients with dysphagia.

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## Table 1

Demographic Characteristics of Study Participants as a Function of Aspiration Status.

| | **Aspirator *N* (%)** | **Non-Aspirator *N* (%)** |
|---|---|---|
| *Age* | | |
| 61-70 | 4 (17.4) | 14 (26.4) |
| 71-80 | 8 (34.8) | 18 (34.0) |
| 81-90 | 11(47.8) | 21 (39.6) |
| *Gender* | | |
| Female | 8 (34.8) | 29 (54.7) |
| Male | 15 (65.2) | 24 (45.3) |
| *Race* | | |
| Caucasian | 22 (95.7) | 43 (81.1) |
| African American | 1 (4.3) | 9 (17.0) |
| Other (Middle East) | 0 (0) | 1 (19) |
| *Weight (kg) (M/SD)* | 81.2 (24.7) | 78.0 (18.4) |
| *BMI (M/SD))* | 26.7 (3.3) | 28.0 (5.0) |
| *Total MMSE Score (M/SD)* | 26.9 (2.3) | 27.1 (2.9) |
| *Smoking* | | |
| Never | 9 (39.1) | 23 (44.2) |
| Current | 3 (13.0) | 2 (3.8) |
| Former | 11 (47.8) | 27 (51.9) |

*Note*. Values in parentheses are the percentages BMI = body mass index; MMSE = Mini-Mental State Examination

## Table 2

Mean Bolus Dwell Times as a Function of Age Group, Liquid Type, Bolus Volume and Delivery Method at the Vallecula.

| | Age (years) | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **61 – 70 (*N* = 18)** | **71 – 80 (*N*= 26)** | **81 – 90 (*N*= 32)** | **61 – 70 (*N* = 18)** | **71 – 80 (*N*= 26)** | **81 – 90 (*N*= 32)** |
| | Water, Cup | | | Water, Straw | | |
| 5 ml | 0.27 (56%) | 0.33 (21%) | 0.34 (40%) | 0.55 (37%) | 0.78 (43%) | 0.69 (53%) |
| 10 ml | 0.39 (22%) | 0.49 (18%) | 0.52 (43%) | 0.46 (28%) | 0.67 (36%) | 0.57 (43%) |
| 15 ml | 0.54 (28%) | 0.46 (14%) | 0.86 (47%) | 2.57 (28%) | 0.49 (39%) | 0.62 (47%) |
| 20 ml | 0.40 (22%) | 0.48 (21%) | 0.45 (50%) | 0.33 (22%) | 0.54 (29%) | 0.49 (53%) |
| | Skim Milk, Cup | | | Skim Milk, Straw | | |
| 5 ml | 0.35 (28%) | 0.54 (36%) | 0.56 (43%) | 0.34 (33%) | 0.78 (57%) | 0.70 (70%) |
| 10 ml | 0.45 (28%) | 0.43 (29%) | 0.54 (47%) | 0.31 (37%) | 0.74 (36%) | 0.62 (50%) |
| 15 ml | 0.27 (37%) | 0.34 (21%) | 0.40 (40%) | 0.28 (22%) | 0.57 (39%) | 0.40 (37%) |
| 20 ml | 0.31 (28%) | 0.27 (14%) | 1.11 (40%) | 0.34 (44%) | 0.50 (25%) | 0.51 (57%) |
| | 2% Milk, Cup | | | 2% Milk, Straw | | |
| 5 ml | 0.45 (28%) | 1.11 (14%) | 0.56 (47%) | 0.28 (37%) | 0.65 (46%) | 0.70 (60%) |
| 10 ml | 0.52 (28%) | 0.33 (21%) | 0.51 (43%) | 0.39 (22%) | 0.51 (46%) | 0.86 (50%) |
| 15 ml | 0.32 (28%) | 0.51 (25%) | 0.42 (53%) | 0.44 (28%) | 0.55 (18%) | 0.70 (50%) |
| 20 ml | 0.27 (17%) | 0.55 (18%) | 0.80 (50%) | 0.56 (22%) | 0.63 (32%) | 0.67 (57%) |
| | Whole Milk, Cup | | | Whole Milk, Straw | | |
| 5 ml | 0.26 (22%) | 0.47 (21%) | 0.45 (47%) | 0.33 (33%) | 1.01 (32%) | 0.77 (60%) |
| 10 ml | 0.28 (11%) | 0.54 (18%) | 0.60 (43%) | 0.26 (37%) | 0.77 (43%) | 0.81 (53%) |
| 15 ml | 0.86 (22%) | 0.44 (21%) | 0.49 (50%) | 0.40 (33%) | 0.53 (39%) | 0.72 (47%) |
| 20 ml | 1.18 (17%) | 0.76 (21%) | 0.47 (50%) | 0.37 (17%) | 0.52 (43%) | 0.57 (43%) |
| | | | | Soy Milk, Straw | | |
| 5 ml | | | | 0.57 (28%) | 0.92 (46%) | 0.83 (67%) |

| | Age (years) | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **61 – 70 (*N* = 18)** | **71 – 80 (*N*= 26)** | **81 – 90 (*N*= 32)** | **61 – 70 (*N* = 18)** | **71 – 80 (*N*= 26)** | **81 – 90 (*N*= 32)** |
| 10 ml | | | | 0.45 (28%) | 0.51 (43%) | 0.70 (57%) |
| 15 ml | | | | 0.48 (37%) | 0.47 (39%) | 0.57 (57%) |
| 20 ml | | | | 0.30 (22%) | 0.63 (39%) | 0.66 (40%) |

*Note*. For each group, means were calculated for all bolus dwell times greater than zero. The percentage of participants within each age group who had a bolus dwell time greater than zero is provided in parentheses to the right of the bolus dwell time mean. The soy milk, cup condition was not acquired from participants to limit total volume consumed in one sitting.

## Table 3

Mean Bolus Dwell Times as a Function of Aspiration Status, Age Group, Puree Type, and Bolus Volume at the Vallecula.

| | **Age (years)** | | |
|---|---|---|---|
| **Volume** | **61 – 70 (*N* = 18)** | **71 – 80 (*N* = 26)** | **81 – 90 (*N* = 32)** |
| | Apple Sauce | | |
| 5 ml | 0.43 (11%) | 1.18 (36%) | 1.20 (33%) |
| 10 ml | 0.70 (11%) | 0.77 (29%) | 1.33 (33%) |
| | Pudding | | |
| 5 ml | 1.39 (17%) | 0.94 (32%) | 2.46 (37%) |
| 10 ml | 1.27 (22%) | 0.96 (29%) | 1.86 (43%) |

*Note*. For each group, means were calculated for all bolus dwell times greater than zero. The percentage of participants within each age group who had a bolus dwell time greater than zero is in parentheses to the right of the bolus dwell time mean.

## Table 4

Mean Bolus Dwell Times as a Function of Aspiration Status, Age Group, and Viscosity at the Vallecula.

| | **Age (years)** | | |
|---|---|---|---|
| **Volume** | **61 – 70** | **71 – 80** | **81 – 90** |
| | Two Percent Milk, Cup | | |
| 10 ml | 0.52 (28%) | 0.33 (21%) | 0.51 (43%) |
| | Apple Sauce | | |
| 10 ml | 0.70 (11%) | 0.77 (29%) | 1.33 (33%) |
| | Pudding | | |
| 10 ml | 1.27 (22%) | 0.96 (29%) | 1.86 (43%) |
| | Graham Cracker | | |
| 2 gm | 1.43 (28%) | 1.28 (25%) | 2.28 (40) |

*Note*. For each group, means were calculated for all bolus dwell times greater than zero. The percentage of participants within each age group who had a bolus dwell time greater than zero is provided in parentheses to the right of the bolus dwell time mean.

## Table 5

Mean Bolus Dwell Times as a Function of Aspiration Status, Age Group, Liquid Type, Bolus Volume, and Delivery Method at the Pyriform Sinuses.

| | **Age (years)** | | | | | |
|---|---|---|---|---|---|---|
| **Volume** | **61 – 70 (*N* = 18)** | **71 – 80 (*N*= 26)** | **81 – 90 (*N*= 32)** | **61 – 70 (*N* = 18)** | **71 – 80 (*N*= 26)** | **81 – 90 (*N*= 32)** |
| | Water, Cup | | | Water, Straw | | |
| 5 ml | 0.29 (11%) | 0.17 (4%) | 0.29 (17%) | 0.70 (17%) | 0.72 (21%) | 0.64 (20%) |
| 10 ml | 0.42 (6%) | 0.28 (7%) | 0.32 (13%) | 0 | 0.52 (18%) | 0.50 (23%) |
| 15 ml | 1.16 (6%) | 0.61 (7%) | 0.82 (17%) | 0.32 (11%) | 0.48 (21%) | 0.80 (13%) |
| 20 ml | 0.75 (6%) | 0 | 0.49 (13%) | 0 | 0.63 (7%) | 0.56 (23%) |
| | Skim Milk, Cup | | | Skim Milk, Straw | | |
| 5 ml | 0.20 (6%) | 1.08 (11%) | 0.61 (27%) | 0 | 0.67 (25%) | 0.59 (37%) |
| 10 ml | 0.87 (6%) | 0.87 (4%) | 0.43 (20%) | 0.53 (6%) | 0.69 (14%) | 0.48 (20%) |
| 15 ml | 0.25 (6%) | 0.98 (4%) | 0.48 (17%) | 0.17 (11%) | 0.57 (11%) | 0.47 (17%) |
| 20 ml | 0 | 0 | 0.59 (17%) | 0.35 (11%) | 0.48 (14%) | 0.53 (27%) |
| | 2% Milk, Cup | | | 2% Milk, Straw | | |
| 5 ml | 0.33 (11%) | 1.74 (7%) | 0.39 (20%) | 0 | 0.48 (18%) | 0.63 (23%) |
| 10 ml | 0 | 0.22 (4%) | 0.58 (13%) | 0.42 (11%) | 0.49 (21%) | 0.63 (20%) |
| 15 ml | 0.19 (6%) | 1.50 (4%) | 0.45 (10%) | 1.35 (6%) | 0.44 (18%) | 0.64 (23%) |
| 20 ml | 0 | 1.31 (4%) | 0.76 (20%) | 0.86 (11%) | 0.69 (14%) | 0.51 (37%) |
| | Whole Milk, Cup | | | Whole Milk, Straw | | |
| 5 ml | 0 | 0.57 (3%) | 0.70 (13%) | 0.60 (6%) | 0.68 (25%) | 0.66 (33%) |
| 10 ml | 0.33 (6%) | 0.30 (7%) | 0.76 (17%) | 0.20 (6%) | 0.70 (18%) | 0.76 (37%) |
| 15 ml | 0.20 (6%) | 0.60 (7%) | 0.47 (20%) | 0 | 0.79 (14%) | 0.61 (23%) |
| 20 ml | 1.57 (6%) | 0.60 (14%) | 0.50 (23%) | 0 | 0.54 (14%) | 0.46 (17%) |
| | | | | Soy Milk, Straw | | |
| 5 ml | | | | 0.39 (6%) | 0.93 (18%) | 0.72 (40%) |

|  | Age (years) |  |  |  |  |  |
|---|---|---|---|---|---|---|
| **Volume** | **61 – 70 (*N* = 18)** | **71 – 80 (*N*= 26)** | **81 – 90 (*N*= 32)** | **61 – 70 (*N* = 18)** | **71 – 80 (*N*= 26)** | **81 – 90 (*N*= 32)** |
| 10 ml |  |  |  | 0 | 0.33 (18%) | 0.64 (33%) |
| 15 ml |  |  |  | 0.57 (11%) | 0.65 (14%) | 0.69 (23%) |
| 20 ml |  |  |  | 0 | 0.85 (14%) | 0.76 (13%) |

*Note**. For each group, means were calculated for all bolus dwell times greater than zero. The percentage of participants within each age group who had a bolus dwell time greater than zero is provided in parentheses to the right of the bolus dwell time mean. The soy milk, cup condition was not acquired from participants to limit total volume consumed in one sitting.

Note+. One outlier was removed from the mean calculations corresponding to a patient in the 71 - 80 year old age group under the condition of 15 cc of skim milk, using a straw. This patient's bolus dwell time was 10 s with this condition; inclusion of this patient's bolus dwell time would increase the mean for that condition and cohort from 0.57 s to 2.93 s.