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Effects of Bolus Size on Swallow Safety: A Systematic Review of External Evidence

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Structured Abstract

Clinical Question: Among individuals who have been diagnosed with thin liquid aspiration by instrumental evaluation, does sipping one measured small sip (i.e., regulated to volume of 1 to 5 mL per sip) versus unregulated sip sizes reduce the frequency of or even completely eliminate aspiration when evaluated instrumentally?

Method: Systematic Review

Study Sources: Cochrane, PubMed, CINAHL, ASHA website, ASHAWire, and PsycINFO

Search Terms: The following specific search term formulas were carefully selected to ensure a focused search of the external evidence.

Aspiration AND swallow* AND (bolus* OR sip*)

Aspiration AND swallow* AND (metered sip* OR regulated sip* OR pace* OR volume*)

Aspiration AND bolus* AND (fiberoptic endoscopic evaluation of swallowing OR modified barium swallow study OR videofluoroscopic swallow study OR instrumental evaluation)

Dysphagia AND (bolus* OR sip*)

Dysphagia AND (metered sip* OR regulated sip* OR pace* OR volume*)

Dysphagia AND bolus* AND (fiberoptic endoscopic evaluation of swallowing OR modified barium swallow study OR videofluoroscopic swallow study OR instrumental evaluation)

Swallow* AND (bolus* OR sip*)

Swallow* AND (metered sip* OR regulated sip* OR pace* OR volume*)

Swallow AND bolus* AND (fiberoptic endoscopic evaluation of swallowing OR modified barium swallow study OR videofluoroscopic swallow study OR instrumental evaluation)

Number of Studies Included: 8

Primary Results:

Smaller bolus volumes were associated with lower penetration-aspiration scale (PAS) than larger volumes, suggesting that smaller bolus volumes are safer for swallowing (Butler et al., 2010; Daggett, Logemann, Rademaker, & Pauloski, 2006). Furthermore, larger bolus volumes led to penetration more often than smaller bolus volumes (Ekberg, Olsson, & Sundgren-Borgström, 1988).

For some populations (e.g., individuals who have trouble generating pharyngeal pressure), larger bolus volumes may be safer for swallowing (Butler et al., 2009; Gokyigit et al., 2009).

Conclusions:

Evidence gathered from the appraised studies suggests that a small bolus size (e.g., 1, 3, or 5 mL) decreases the risk of penetration or aspiration of liquids during swallowing events.

Patients' diagnosis or disorder, individual age, nutrition, hydration, and positioning needs should be considered before making a recommendation about liquid bolus size.

Effects of Bolus Size on Swallow Safety: A Systematic Review of External Evidence

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Clinical Scenario

Megan, a 9-year-old female, has an extensive medical history (see Appendix to view full medical history) that has led to a diagnosis of a swallowing disorder, or oropharyngeal dysphagia. Oral dysphagia can be defined as a disorder of sucking, chewing, or transferring boluses into the pharynx (American Speech-Language-Hearing Association [ASHA], 2016). Traditionally, pharyngeal dysphagia is defined as penetration or aspiration of a bolus, a mass of food or liquid, into the airway (Daniels et al., 2009). Instrumental video swallow studies were conducted at 4 and 6 years old and a fiberoptic endoscopic evaluation of swallowing (FEES) was conducted at 1 year old to evaluate Megan's swallowing. All three of these early swallow studies revealed both penetration and silent aspiration of thin liquids; in other words, Megan did not cough on thin liquids when the material entered her airway. Megan's swallowing abilities were further complicated by oral phase dysphagia, as well as respiratory and airway management issues, leading to concerns with weight gain and growth.

Recent therapy sessions have focused on the following treatments: functional oral motor movement with guided chewing, visual feedback with the use of a mirror and charts, oral care techniques to aid motor patterns for clearing mouth of residue including spitting, and a modified supraglottic swallow sequence (i.e., hold bolus, swallow, cough, swallow again). These treatments have led to progress in Megan's swallowing status by resolving oral aversion, improving chewing and bolus control, and practicing a timely initiation of swallow with solid and puree textures. However, Megan continues to demonstrate a mild delay in initiation of her swallow with thin liquids using a single-sip open cup and single-sip narrow juice box straw. Because of the progress noted in therapy, a repeat swallow study was conducted at 8 years old and revealed no penetration or aspiration. Current recommendations from her hospital-based speech-language pathologist (SLP) include a slow wean from nectar-thick liquids to 1/2 nectar thick to thin liquids using the strategies of single sips, small bolus size, and slow rate. Further recommendations include upright positioning, cues to place food on the molar surface, and chewing well as needed. Both Megan and her family have expressed a desire for Megan to live as normal a life as possible and participate in simple activities such as taking water sips from the water fountain at school with her friends. Megan's adherence to the recommendations is inconsistent. Per parental report, she often will "sneak" thin liquids and refuse thickened liquid beverages. While recent reports indicate that Megan's signs and symptoms of swallowing difficulty with oral intake are improving, she continues to cough and choke unless she "takes very small sips."

Megan's desire to drink similar liquids as her peers is not unlike many other individuals with a diagnosis of oropharyngeal dysphagia requiring extended swallowing therapy. In the pediatric hospital where Megan received speech therapy, a common recommendation for facilitating a safe swallow is a reduction in bolus size. Our research team decided to conduct a review of the external evidence to determine the level of support for the recommendation of reducing bolus size to decrease the frequency of aspiration or to eliminate it altogether.

The Clinical Question

A PICO framework was used to develop a clinically relevant research question. The population (P), intervention (I), comparison intervention (C), and intended outcome (O) were defined in the following clinical question: Among individuals who have been diagnosed with thin liquid

aspiration by instrumental evaluation (P), does sipping one measured small sip (i.e., regulated to volume of 1 to 5 mL per sip; I) versus unregulated sip sizes (C) reduce the frequency of or even completely eliminate aspiration (O) when evaluated instrumentally?

Search for the Evidence

Inclusion Criteria

To ensure a focused literature search centered on research studies related to bolus volume and aspiration, the research team established the following inclusion criteria: 1) study participants with either normal swallowing function or impaired swallowing function, 2) participants with impaired swallowing function secondary to neurological disease or normal aging, 3) at least one of the study's independent variables aimed to impact the participants' swallowing function, 4) and, as a first step of ensuring quality, the study must have been published in a peer-reviewed journal.

Exclusion Criteria

The following exclusion criteria were established: 1) study participants with impaired swallowing secondary to progressive diseases (e.g., dementia, ALS), structural abnormalities and changes (e.g., tracheostomy, ventilator, cleft palate), or head and neck cancers, 2) papers centered on bolus viscosity rather than bolus volume, 3) research articles written in languages other than English, and 4) research articles without human subjects.

Search Strategy

The research team conducted a search in the following databases: Cochrane, PubMed, CINAHL, ASHA website, ASHAWire, and PsycINFO. The search terms consisted of the following: aspiration, swallow, bolus, sip, metered sip, regulated sip, pace, volume, fiberoptic endoscopic evaluation of swallowing, modified barium swallow study, videofluoroscopic swallow study, instrumental evaluation, and dysphagia. These individual search terms were assembled into multiple search term equations and used within each of the searched databases (see Table 1).

Database Search Results

A comprehensive search of the PubMed database resulted in 5,151 papers. Of these papers, 65 were considered relevant after a review of the abstracts, with the remaining articles discarded based on exclusionary criteria. A search in the Cochrane Database of Systematic Reviews yielded a total of 171 results of which 6 abstracts were considered relevant and 165 irrelevant. A search in the CINAHL (Cumulative Index to Nursing and Allied Health Literature) database resulted in 763 total studies, 99 of which were kept and 664 of which were not kept as they included one or more of the exclusionary criteria. The PsycINFO database resulted in 293 studies; 36 articles were considered relevant and the rest were eliminated. Seventy-two articles were found using the ASHAWire database. Eight studies were kept for consideration in this paper, and 64 articles were discarded. Finally, a separate search was conducted on the ASHA website, which resulted in 5,410 articles. Fifty-nine studies were kept for further review and 5,351 studies were eliminated for reasons similar to the examples provided above. After combining the relevant articles from all of the searched databases, 273 articles remained. After removal of duplicates, 39 studies remained and were read in full to determine if they fully met the inclusion and exclusion criteria for critical appraisal. Following this analysis, 8 papers were deemed appropriate for appraisal. Three appraised articles were judged as the most informative and complete, and were chosen to complete hand searching. Hand searching consisted of reviewing each of the research articles referenced in the three appraised studies. No new articles were added via hand searching.

Evaluating the Evidence

Methods for the appraisal of the eight included studies followed the Cincinnati Children's Hospital Medical Center (CCHMC) critical appraisal process. This process provides rating guidelines and review of the methods, selection bias, validity, reliability, applicability, confounders, blinding, data collection, treatment of withdrawals, and evidence level for each study included. Effect sizes were reported and interpreted as part of the appraisal process (see Table 4). All eight studies were evaluated through a collaborative process by two members of the research team. Areas of disagreement were resolved by consensus. A summary of the participants,

methods, and results for all eight studies is presented in Table 4.

Quality of Evidence

To determine the quality of evidence, several factors were taken into consideration and evaluated across all studies. Blinding of raters was not used in all of the studies (Butler et al., 2009; Butler et al., 2010; Daggett et al., 2006; Ekberg et al., 1988; Gokyigit et al., 2009; Kuhlemeier, Palmer, & Rosenberg, 2001). Although raters were blinded to participants across all studies, raters were not always blinded to the bolus condition presented to participants. As such, these raters may have been biased due to preconceived opinions and prior clinical experiences about swallowing performances for specific bolus sizes.

Statistical measures including means and standard deviations were absent in some studies. For example, Ekberg et al. (1988) did not provide information regarding statistical analysis of results, confidence intervals, and confounding factors. Additionally, participants were administered different patterns of bolus volumes. Some participants received bolus volumes in order of small to large, while some received boluses in order from large to small. Similarly, Daggett et al. (2006) reported that participants in their study were not administered boluses following the same protocol, greatly reducing the validity and reliability of this particular study. Adverse events affecting patients, such as risk of pneumonia, were not explicitly explained in all studies. Fraser and Steele (2012) did not state whether or not patients were currently receiving or had received dysphagia therapy at the time of the study. Information about conflicts of interest was commented on in only three articles (Butler et al., 2009; Butler et al., 2010; Fraser & Steele, 2012). Only one of the eight studies provided information about the reliability and validity of instruments used (Butler et al., 2009). In this study, all instruments were used as part of standard clinical practice and are considered adequate for collecting the outcome data reported in the study.

Effect sizes were provided in one study (Butler et al., 2009) and calculated in three additional studies (Butler et al., 2010; Butler et al., 2011; Gokyigit et al., 2009). The remaining four studies did not provide measures of means and standard deviations, which are required to calculate effect size. In the three studies for which effect size could be calculated, a large effect size was adopted as greater than +/- 0.80 (Dollaghan, 2007). Effect sizes reported or calculated for these four studies were interpreted as large. Details about the effect sizes from individual studies follow.

Large effect size differences were calculated by the research team using the results provided in Butler et al. (2010), which reported various bolus volumes and their effects on penetration-aspiration scale (PAS) scores in healthy adults. The effect sizes were determined as the following (regarding PAS scores): 5 mL & 15 mL = -2.67; 5 mL & 20 mL = -3.88; 10 mL & 15 mL = -2.12; 10 mL & 20 mL = -3.22; 15 mL & 20 mL = -1.29. Additional effect sizes were obtained directly from Butler et al. (2011), which provided the following large effect sizes between accepted bolus volume (relating to PAS scores): straw and cup = 1.47; 5 mL & 20 mL = -2.32; 10 mL & 20 mL = -2.00; 15 mL & 20 mL = -2.52. The large effect sizes provide evidence to support the claim that smaller boluses result in decreased penetration and aspiration.

Grade for the Body of Evidence

Based on the completed evaluation of research factors, the appraised body of evidence was given an overall grade of moderate quality. A moderate grade for the body of evidence was assigned due to these factors and because descriptive and cross-sectional study designs (observational studies in which researchers document what occurs when the study participants receive the intervention, and when intervention effects are compared between varied age groups) are considered to be lower quality evidence when compared to study designs such as randomized controlled trials (when participants are randomly selected to receive one of many treatment interventions).

The Evidence-Based Decision

In the clinical case study mentioned previously, Megan would likely benefit from the recommendation of a small bolus size due to the results from her most recent video swallow study. During the study, a small thin liquid bolus was administered and there was no penetration or aspiration of the bolus. Research has shown that regulating sip sizes to 5 mL may help resolve Megan's wet vocal quality and chest congestion by reducing her risk of aspiration and penetration (Butler et al., 2010; Butler et al., 2011; Daggett et al., 2006; Ekberg et al., 1988; Fraser & Steele, 2012; Kuhlemeier et al., 2001).

Findings from the appraised studies provide important implications for both assessment and intervention for individuals with dysphagia. While some of the appraised studies found that smaller volumes reduced the risk of aspiration, other studies found that larger volumes were safer for swallowing. Butler et al. (2010) and Daggett et al. (2006) revealed that smaller bolus volumes (5, 10, and 15 mL vs. 20 mL; and 1, 3, and 5 mL vs. 10 mL, respectively) were associated with lower PAS scores when compared to larger volumes, suggesting that smaller bolus volumes are safer for swallowing. Butler et al. (2011) also revealed lower PAS scores for smaller boluses (i.e. 5 vs. 15 mL, 5 vs. 20 mL, 10 vs. 15 mL, 10 vs. 20 mL, and 15 vs. 20 mL). These findings give evidence to support the implementation of small sip sizes and bites with patients with dysphagia in clinical practice. Butler et al. (2011) found that 36% of participants demonstrated aspiration at some point during the study, showing a wide variety of normal swallowing patterns among healthy adults.

Larger bolus volumes have been found by many to lead to penetration more often than smaller bolus volumes (Dodds et al., 1988; Ekberg et al., 1988; Kahrilas, Lin, Chen, & Logemann, 1996; Nagy, Molfenter, Péladeau-Pigeon, Stokely, & Steele, 2014). This finding is important clinically, as patients with dysphagia may have difficulty with premature spillage and general control of a larger bolus.

In contrast, Butler et al. (2009) found that larger bolus volumes facilitated swallowing safety in individuals who had trouble generating pharyngeal pressure. Researchers found that a bolus of a larger weight (e.g., 10 mL) travels at a greater velocity than one of a lesser weight (e.g., 5 mL), thus requiring less pharyngeal pressure to propel the bolus through the pharynx. Gokyigit et al. (2009) also found larger bolus sizes to be safer for swallowing by examining the time interval between the closing of the glottis and the opening of the upper esophageal sphincter (UES) when different bolus volumes are swallowed. Results indicate that larger boluses pass through the oropharynx at a faster rate than smaller boluses and that individuals respond to larger boluses earlier with more consistent onset of airway protection. This suggests that smaller sips are not guaranteed to contribute to safer swallowing for all individuals—for example, people with deficits in generating pharyngeal pressure during the swallow and those that require increased sensory input (Butler et al., 2009; Gokiygit et al., 2009). Smaller sips likely require more pharyngeal pressure and provide less sensory input and cannot be a guaranteed solution to chronic aspiration in all patients. For Megan, the suggestion for larger bolus volumes is not appropriate, as she does not have difficulty generating pharyngeal pressure nor does she have sensory input deficits.

The recommendation for administering small bolus volumes cannot be broadly applied across all clinical populations. A patient's individual diagnosis or disorder, age, nutrition, hydration, and positioning needs should be considered before making this specific recommendation. For example, patients should self-feed if possible in order to increase sensory input and coordinate timing of their swallow (Fraser & Steele, 2012). However, straws should not be used to control bolus size when self-feeding because straws cannot deliver a regulated bolus volume (Butler et al., 2011; Clark, Anderson, & Hietpas, 2014).

Conclusion

Overall, the evidence gathered from the appraised studies generally supports the clinical hypothesis that a small bolus size (5 mL or smaller) decreases the risk of penetration or aspiration of liquids during swallowing events. Six of the eight studies provide evidence that supports the administration of small bolus sizes (Butler et al., 2010; Butler et al., 2011; Daggett et al., 2006; Ekberg et al., 1988; Fraser & Steele, 2012; Kuhlemeier et al., 2001). Overall, the studies reported lower PAS scores when individuals were given smaller bolus volumes (Butler et al., 2010; Butler et al., 2011; Daggett et al., 2006). Specifically, Daggett et al. (2006) revealed that bolus sizes of 1, 3, and 5 mL are small enough to result in lower PAS scores as compared to boluses of 10 mL and above. These results support the recommendation for Megan to receive liquid bolus volumes of 5 mL or smaller.

The conclusions from this study should be cautiously interpreted when being applied to pediatric populations. During the search for external evidence, no studies that centered on pediatric patients fit the inclusion and exclusion criteria established by the researchers. In an effort to use the most relevant evidence available, the authors elected to use studies with adult subjects, even though the case study focused on a pediatric patient. Therefore, more research is needed that is centered on regulating bolus volume to decrease the risk of aspiration in pediatric populations.

Authors' Notes

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Karen Rizzo is a speech-language pathologist at Cincinnati Children's Hospital Medical Center. She specializes in the areas of oral motor feeding and dysphagia and fluency disorders. Her specific focus is working with children and families impacted by feeding and swallowing disorders.

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Leah Mong completed her undergraduate studies at Ohio State University in 2014 and continued on to Miami University, where she earned her master's degree in 2016. Following graduation, Leah began her career working at Dayton Children's Hospital.

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Isla Katz, MS, CF-SLP
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Isla Katz completed her undergraduate studies at the University of Minnesota in 2014. She went on to complete her graduate studies at Miami University in May 2016 and plans to begin her career working with the pediatric population.

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Dr. Scarborough is an associate professor at Miami University who specializes in pediatric feeding and swallowing.

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Daggett, A., Logemann, J., Rademaker, A., & Pauloski, B. (2006). Laryngeal penetration during deglutition in normal subjects of various ages. *Dysphagia, 21*(4), 270–274.

Daniels, S. K., Schroeder, M. F., DeGeorge, P. C., Corey, D. M., Foundas, A. L., & Rosenbek, J. C. (2009). Defining and measuring dysphagia following stroke. *American Journal of Speech-Language Pathology, 18*(1), 74–81. doi: 10.1044/1058-0360(2008/07-0040)

Dodds, W. J., Man, K. M., Cook, I. J., Kahrilas, P. J., Stewart, E. T., & Kern, M. K. (1988). Influence of bolus volume on swallow-induced hyoid movement in normal subjects. *American Journal of Roentgenology, 150*(6), 1307–1309.

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Kahrilas, P. J., Lin, S., Chen, J., & Logemann, J. A. (1996). Oropharyngeal accommodation to swallow volume. *Gastroenterology, 111*(2), 297–306.

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Table 1. Search Terms

Aspiration AND swallow* AND (bolus* OR sip*)
Aspiration AND swallow* AND (metered sip* OR regulated sip* OR pace* OR volume*)
Aspiration AND bolus* AND (fiberoptic endoscopic evaluation of swallowing OR modified barium swallow study OR videofluoroscopic swallow study OR instrumental evaluation)
Dysphagia AND (bolus* OR sip*)
Dysphagia AND (metered sip* OR regulated sip* OR pace* OR volume*)
Dysphagia AND bolus* AND (fiberoptic endoscopic evaluation of swallowing OR modified barium swallow study OR videofluoroscopic swallow study OR instrumental evaluation)
Swallow* AND (bolus* OR sip*)
Swallow* AND (metered sip* OR regulated sip* OR pace* OR volume*)
Swallow AND bolus* AND (fiberoptic endoscopic evaluation of swallowing OR modified barium swallow study OR videofluoroscopic swallow study OR instrumental evaluation)

Table 2. Search Procedure

An initial search of six databases was successful in finding 11,860 articles.					
Cochrane	**PubMED**	**CINAHL**	**ASHA Website**	**PyscINFO**	**ASHAWire**
⇩					
Initial search of Cochrane yielded **171** articles	Initial search of PubMED yielded **5,151** articles	Initial search of CINAHL yielded **763** articles	Initial search of ASHA website yielded **5,410** articles	**Initial search of PyscINFO yielded 293** articles	**Initial search of ASHAWire yielded 72** articles
⇩					
6 articles were kept for review and **165** were discarded based on the exclusion criteria outlined in *Table 3*	**65** articles were kept for review and **5,086** were discarded based on the exclusion criteria outlined in *Table 3*	**99** articles were kept for review and **664** were discarded based on the exclusion criteria outlined in *Table 3*	**59** articles were kept for review and **5,351** were discarded based on the exclusion criteria outlined in *Table 3*	**36** articles were kept for review and **257** were discarded based on the exclusion criteria outlined in *Table 3*	**8** articles were kept for review and **64** were discarded based on the exclusion criteria outlined in *Table 3*
⇩					
Duplicate articles were removed by hand after all database searches had been completed. After removal of these duplicates, **39** studies were examined more closely to determine if they were adequate for critical appraisal. Following this analysis, **8** papers were deemed appropriate for appraisal. Lastly, **3** appraised articles were judged as the most informative and complete, and were chosen to complete hand searching. **No** new articles were added via hand searching.					

Table 3. Exclusionary Criteria

Studies not focused on dysphagia or swallowing
Aspiration/dysphagia of control/comparison in study not related to bolus size
Treatment of dysphagia/aspiration in study not related to bolus size
Study participants with progressive diseases such as dementia, Parkinson's disease, and muscular dystrophy
Study participants with structural abnormalities of the swallowing mechanism, such as laryngectomy
Study participants with head and neck cancer
Study participants with intellectual or cognitive disabilities
Studies focused on tests, screenings, or evaluations for dysphagia
Studies focused on oral phase of the swallow (e.g., mastication and saliva management), esophageal phase of the swallow, or sucking pressure
Studies focused on respiration or pressure during the swallow
Studies only focused on sequential swallowing
Studies focused on the reason for the onset or cause of dysphagia
Studies focused on dysphagia caused by medication or radiation
Studies focused on obstructive sleep apnea

Table 4. Summary of Critical Appraisals

Summary of Studies With a Body of Evidence Classified as 4a				
Butler, S. G., Stuart, A., Castell, D., Russell, G. B., Koch, K., & Kemp, S. (2009). Effects of age, gender, bolus condition, viscosity, and volume on pharyngeal and upper esophageal sphincter pressure and temporal measurements during swallowing. *Journal of Speech, Language, and Hearing Research, 52,* 240–253.				
Design Cross-sectional	**Participants** 23 young adults (11 males, 12 females) ages 20–40 years (*M* = 30 years) and 21 older healthy adults (11 males, 10 females) ages 66–84 years (*M* = 75 years) **Study Protocol** Each participant swallowed 18 times (thin, nectar-thick, honey-thick, and pudding-thick liquids of 5 and 10 mL each, plus one saliva swallow).	**Dependent Variables** Upper and lower pharyngeal and upper esophageal sphincter (UES) pressures, durations, and onsets as determined by manometric measurements. Younger adults had a significantly greater relaxation of the UES during saliva swallows (p = 0.002, alpha = 0.05).	**Significant Findings** Viscosity (p < 0.0001), volume (p < 0.0001), two-way interactions of volume × gender (p = 0.025) and volume × viscosity (p < 0.001), and three-way interactions of volume × age × gender (p = 0.003) and viscosity × volume × gender (p = 0.038)	**Conclusion(s)** Larger volume was predicted to elicit longer pharyngeal pressure duration, however, results revealed the opposite. One hypothesis purported for the unexpected finding is that a 10 mL bolus can capitalize on weight, velocity, and gravity. In contrast, a 5 mL bolus is more dependent on pharyngeal forces from above to through the pharynx. Results of this study suggest smaller sips are not guaranteed to contribute to safer swallowing and are not a solution to chronic aspiration.
Butler, S. G., Stewart, A., Leng, X., Rees, C., Williamson, J., & Kritchevsky, S. B. (2010). Factors influencing aspiration during swallowing in healthy older adults. *The Laryngoscope, 120,* 2147–2152.				
Design Cross-sectional	**Participants** 76 healthy older adults: 18 from ages 61–70 years old, 28 from 71–80 years old, and 30 from 81–90 years old. **Study Protocol** Each participant swallowed 32 boluses: four liquid boluses (water, skim milk, two percent milk, and whole milk), four volumes (5, 10, 15, and 20 mL), two delivery methods (straw and cup).	**Independent Variables** Age, sex, liquid type, delivery method, and bolus volume **Dependent Variable** Participants' scores on the penetration-aspiration scale (PAS).	**Significant Findings** Included liquid type (p = 0.0001), bolus volume (p = 0.02), and delivery method (p = 0.04). In general, PAS scores were higher for milk swallows than water swallows, higher for larger than for smaller boluses, and higher for straw than for cup delivery. Calculated effect sizes (significant = > +/- 0.80): water & skim milk (-3.50), water & 2% milk (-6.40), water & whole milk (-5.12), skim & 2% milk (-3.18), skim & whole milk (-2.22), 5 mL & 15 mL (-2.67), 5 mL & 20 mL (-3.88), 10 mL & 15 mL (-2.12), 10 mL & 20 mL (-3.22), 15 mL & 20 mL (-1.29)	**Conclusion(s)** Results provided evidence that supports the administration of small bolus sizes.

Table 4. Summary of Critical Appraisals (continued)

Butler, S. G., Stuart, A., Case, L. D., Rees, C., Vitolins, M., & Kritchevsky, S. B. (2011). Effects of liquid type, delivery method, and bolus volume on penetration-aspiration scores in healthy older adults during flexible endoscopic evaluation of swallowing. *Annals of Otology, Rhinology, and Laryngology, 120*(5), 288–295.				
Design Cross-sectional	**Participants** 14 healthy adults ages 65+ years (*M* = 75) **Study Protocol** Each participant swallowed four liquid boluses (water, skim milk, 2% milk, whole milk) of 5, 10, 15, and 20 mL each by cup and straw.	**Dependent Variables** Participants' scores on the PAS	**Significant Findings** PAS scores differed significantly by liquid type (p = 0.003) and bolus volume (p = 0.017) but not delivery method (p = 0.442; 95% CI). PAS scores for the 20 mL bolus (*M* = 2.01) were significantly greater than 5 mL (*M* = 1.44; p = 0.003), 10 mL (*M* = 1.54; p = 0.049), and 15 mL volumes (*M* = 1.43; p = 0.013). Calculated effect sizes (significant = > +/-0.80): water & skim milk (-1.53), water & 2% milk (-3.08), water & whole milk (-2.75), skim & 2% milk (-1.80), skim & whole milk (-1.33), straw & cup (1.47), 5mL & 20mL (-2.32), 10 mL & 20 mL (-2.00), 15 mL & 20 mL (-2.52)	**Conclusion(s)** Results provided evidence that supports the administration of small bolus sizes.
Fraser, S., & Steele, C. M. (2012). The effect of chin down position on penetration-aspiration in adults with dysphagia. *Canadian Journal of Speech-Language Pathology and Audiology, 36*(2), 142–148.				
Design Cross-sectional	**Participants** 42 adults with dysphagia (23 males, 19 females), *M* = 75 years **Study Protocol** Each participant underwent a videofluorscopic swallow study (VFSS) with 38 teaspoon swallows of thin liquid barium using varied head positions (19 neutral head, 19 chin tuck) and 60 cup swallows (30 neutral head, 30 chin tuck).	**Dependent Variable** Participants' scores on the PAS	**Findings** In chin down, cup-sip positions, 36.7% cases had normal airway protection. Penetration into the laryngeal vestibule was more common in the cup-sip condition (50%) than the teaspoon condition (31.6%). Penetration (42.1%) and aspiration (26.3%) were more common in the teaspoon condition (10%) than in the cup-sip condition (3.3%). PAS scores of bolus administration in the chin down position are statistically significant (p = 0.000). Differences in airway invasion scores based on bolus administration in the neutral head position are not statistically significant (p = 0.184).	**Conclusion(s)** Results provided evidence that supports the administration of small bolus sizes.

Table 4. Summary of Critical Appraisals (continued)

Summary of Studies With a Body of Evidence Classified as 4b				
Daggett, A., Logemann, J., Rademaker, A., & Pauloski, B. (2006). Laryngeal penetration during deglutition in normal subjects of various ages. *Dysphagia, 21*(4), 270–274.				
Design Descriptive, retrospective	**Participants** 98 randomly selected, healthy adults (48 males, 50 females) ages 20–94 years selected from files from previous research studies with penetration-aspiration scale (PAS) scores available **Study Protocol** Participants swallowed a mix of bolus volumes and consistencies (1, 3, 5, & 10 mL) of thin liquid, uncontrolled volume cup swallow, 3 mL pudding, 1/4 cookie, and apple bite. Not all subjects received the same combination of boluses. Total swallows included 1,413 evaluated.	**Independent Variables** Volume and viscosity **Dependent Variable** Participants' scores on the PAS	**Findings** More frequent penetration was observed with larger liquid bolus volumes by swallow ($p = 0.02$) and by person ($p = 0.03$).	**Conclusion(s)** Results provided evidence that supports the administration of small bolus sizes.
Ekberg, O., Olsson, R., & Sundgren-Borgström, P. (1988). Relation of bolus size and pharyngeal swallow. *Dysphagia, 3*(2), 69–72.				
Design Cross-sectional	**Participants** 20 patients (12 women, 8 men) with mild dysphagia ages 17–78 years (*M* = 60 years) and 10 patients without dysphagia ages 21–41 years (*M* = 30 years) **Study Protocol** Half of the patients with dysphagia were given liquid boluses (2.5, 5, 10, and 20 mL) in increasing order, and the remaining patients were administered liquid bolus volumes in decreasing order. Those with a normal swallow were given volumes in an increasing order. Cineradiography with a speed frame of 50 frames/second was used.	**Dependent Variable** Velocity of bolus movement from C2 to the PE segment	**Significant Findings** There were no statistically significant findings reported in this study.	**Result(s)** There was a trend of penetration with larger bolus volumes in the patients with dysphagia.

Table 4. Summary of Critical Appraisals (continued)

Gokyigit, M. C., Pazarci, N. K., Ercan, I., Seker, S., Turgut, S., & Ertekin, C. (2009). Identification of distinct swallowing patterns for different bolus volumes. *Clinical Neurophysiology, 120*(9), 1750–1754.				
Design Cross-sectional	**Participants** 14 healthy adults (8 women, 6 men; *M* = 36 years) **Study Protocol** Patients produced 273 swallows of different volumes (saliva, 3, 5, 10, and 15 mL) delivered via syringe for analysis using electromyography (EMG).	**Dependent Variables** Time interval between glottis closure and UES opening. General swallow patterns elicited based on bolus volumes were also described.	**Significant Findings** Significant difference found when comparing saliva and 15 mL bolus on onset thyroarytenoid movement-EMG ($p < 0.0001$).	**Conclusion(s)** Results suggest that larger boluses travel through the oropharynx more quickly than smaller boluses and subjects responded to the larger boluses earlier with more consistent onset of airway protection. Therefore, larger boluses could be safer for some individuals.
Kuhlemeier, K., Palmer, J., & Rosenberg, D. (2001). Effect of liquid bolus consistency and delivery method on aspiration and pharyngeal retention in dysphagia patients. *Dysphagia, 16,* 119–122.				
Design Cross-sectional	**Participants** 190 patients with dysphagia (*M* = 71 years) **Study Protocol** Each participant underwent a videofluorscopic swallow study (VFSS) within a 5-year period. Each patient was administered thin liquid (apple juice) and nectar-thick liquid (apricot juice) via teaspoon and cup, and ultra-thick liquid via teaspoon only.	**Dependent Variables** Ratings of aspiration and pharyngeal residue.	**Significant Findings** Significant findings showed more pharyngeal retention with ultra-thick liquid consistency ($p < 0.001$) than for the thin and nectar-thick liquid consistencies. No significant difference ($p > 0.25$) in pharyngeal retention for the thin and nectar-thick liquids was found. Patients with dysphagia were more likely to aspirate when a bolus was delivered by cup than by spoon (5 mL).	**Conclusion(s)** Results provided evidence that supports the administration of small bolus sizes.

Appendix

Megan, a 9-year-old female, has an extensive medical history. She was born prematurely at 29 weeks gestation with a tracheoesophageal fistula (TEF)[1], esophageal atresia[2] requiring surgical repair at birth, and chronic lung disease associated with her prematurity. Additional diagnoses include failure to thrive, gastroesophageal reflux, esophageal stricture, tracheobronchomalacia[3], subglottic stenosis[4], and chronic pulmonary aspiration. Megan has previously experienced multiple respiratory infections leading to pneumonia and poor weight gain. While Megan's pulmonary health is currently stable and she is receiving 50% of her nutrition and hydration orally, she presents with a persistent daily wet cough and chest congestion that includes wheezing. Due to poor weight gain, oral aversion, and oropharyngeal dysphagia, she was placed on a gastrostomy tube (G-tube) through which she is currently receiving 50% of her nutrition and hydration.

[1] Tracheoesophageal fistula: an abnormal connection between the trachea and esophagus

[2] Esophageal atresia: the esophagus ends in an abnormal pouch rather than connecting to the stomach

[3] Tracheobronchomalacia: the cartilage of the trachea is soft

[4] Subglottic stenosis: the airway below the glottis (the space between the vocal folds) narrows