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Factors Influencing Aspiration During Swallowing in Healthy Older Adults

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Abstract

Objectives/Hypothesis—While flexible endoscopic evaluation of swallowing (FEES) is an established diagnostic tool, little data exist on the effects of varying liquid types on the swallowing outcomes in healthy older adults.

Study Design—Prospective.

Methods—Seventy-six healthy older adult volunteers participated (i.e., 18, 28, and 30 in the 7th, 8th, and 9th decades of life, respectively). The effects of age, gender, liquid type (i.e., water, skim, 2%, and whole milk), delivery method (i.e., cup and straw), and volume (i.e., 5, 10, 15, and 20 ml) on Penetration Aspiration Scale (PAS) scores were assessed during FEES.

Results—Penetration and silent aspiration were observed in 83% and 28% of the participants, respectively. This represented 19% and 3% of participants' 2,432 swallows, respectively. Liquid type ($p = 0.0001$), bolus volume ($p = 0.02$) and delivery method ($p = 0.04$) significantly affected PAS scores. PAS scores were significantly ($p < 0.05$) greater for: milk versus water swallows; whole versus skim milk swallows; 10 and 20 ml versus 5 ml volumes; and straw versus cup delivery. The risk for aspiration increased by approximately 2, 3 and 7 fold with maximal increases in bolus volume, fat content of liquids, and age, respectively.

Conclusions—Occasional aspiration may be an underappreciated phenomenon during FEES in healthy older adults. In addition, milk yielded a higher likelihood of aspiration than water. Accordingly, different liquid types, bolus volumes, and delivery methods should be utilized to assure an accurate assessment of aspiration status in healthy older adults.

Level of Evidence = **2c**

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Conflict of Interest: None

Keywords

swallowing; aspiration; FEES; older adults; liquid; delivery method; bolus volume

Introduction

Flexible endoscopic evaluation of swallowing (FEES) is now routinely used to assess aspiration in outpatient and inpatient populations. Furthermore, the sensitivity of FEES is comparable, if not superior, to that of videofluoroscopic swallowing examination (VFSE) in the detection of aspiration (1-4). However, many aspects of the FEES protocol may vary among clinicians, and it is unclear how this variation might affect testing results. For example, bolus types are not standardized. Furthermore, we recently reported higher penetration aspiration scale (PAS) scores (5) on milk versus water swallows in 14 healthy older adults [in review]. There was a significant difference between skim and whole milk PAS scores, suggesting that the higher the fat content of the liquid, the greater risk for aspiration. If only water is tested during FEES, the risk for aspiration may be underappreciated. Likewise, if skim milk alone and not whole milk was tested, the risk for aspiration may also be underappreciated. In the same study [in review], we also found that bolus delivery (i.e., straw vs. cup delivery) and bolus size (i.e., the larger 20 ml) yielded significantly more severe PAS scores.

Given the potential magnitude of our previous findings on FEES outcomes in healthy older adults, we sought to replicate and extend our previous pilot study with a larger sample size. Accordingly, the effects of age, gender, liquid type (i.e., water, skim, 2%, and whole milk), delivery method (i.e., cup and straw), and volume (i.e., 5, 10, 15, and 20 ml) on PAS scores were assessed during FEES. Thus, from previous research, we hypothesized that higher fat content of liquids, larger volumes, and straw delivery would evoke higher PAS scores in healthy older adults.

Materials and Methods

Participants

Seventy-six adults volunteered to participate in the study. They included 18 participants from 61-70 years old (*M* = 65.9 years, *SD* = 1.9), 28 participants from 71-80 years old (*M* = 77.6 years, *SD* = 2.0), and 30 participants from 81-90 years old (*M* = 83.8 years, *SD* = 2.3). Participants reported no history of swallowing, speech, and voice problems; no known neurologic or otolaryngologic disorders. All participants were ambulatory and reported they were in good health. Participants were recruited by bulletins approved by the Wake Forest University Health Sciences Institutional Review Board. Informed consent was obtained.

Apparatus

A KayPENTAX Swallowing Workstation (KayPENTAX, Inc., Lincoln Park, NJ) with a PENTAX VNL 1070 STK naso-pharyngo-laryngoscope and PENTAX EPK-1000 Digital Color Video Processors were utilized for conducting the FEES.

Procedure

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 moved throughout the study between swallowing and post-swallow positions to collect the data.

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Swallowing position required that the distal end of the endoscope was just above the top of the epiglottis so that the entire base of tongue, the tip of the epiglottis, posterior pharyngeal wall, lateral pharyngeal walls (e.g., lateral channels), and laryngeal vestibule were visualized prior to bolus administration. The endoscope was maintained in swallowing position throughout bolus administration and was moved only while the scope was advanced to post-swallow position following a bolus presentation. To obtain post-swallow position, the distal end of the scope was advanced lower into the pharynx, past the tip of the epiglottis and into the upper portion of the laryngeal vestibule where the glottis and trachea below could be well visualized. Post-swallow position was only held long enough to determine the PAS score, and then the scope was pulled back into swallowing position.

Four liquid boluses (i.e., water, skim milk, two percent milk, and whole milk) with four volumes (i.e., 5, 10, 15, and 20 ml) were administered with two delivery methods (i.e., straw vs. cup). 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, Illinois). Participants were instructed prior to bolus administration that once handed a cup to swallow all liquid in one swallow when ready (6); 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 PAS score in accordance with previously published methods (5, 7, 8). Higher PAS scores reflect more abnormal swallows (Table 1). A PAS score of 1 is a normal swallow with no material in the airway, scores between 2 and 5 indicate that material entered the laryngeal vestibule (i.e., penetration), and scores of 6-8 indicate that material passed below the vocal cords into the trachea (i.e., aspiration).

Data Analysis

A total of 2,432 data points were available for statistical analyses (i.e., 76 participants × 32 swallows). All swallows were scored with the 8-point PAS. A five-factor linear mixed model analysis of variance (ANOVA) was used to examine the effect of liquid type, delivery type, bolus volume, gender and age on the PAS scores. Since PAS scores were highly skewed, ranks were used in place of the PAS scores. A compound symmetry covariance structure was used to model the within-patient correlation. Linear contrasts were used to assess the pair-wise differences among the levels of significant main effects.

A logistic regression model was used to further investigate the relationship for penetration and aspiration status with predictor factors (i.e., liquid type, bolus volume, delivery method, and age). An odds ratio for each factor was obtained for penetration and aspiration, respectively, indicating the relative risk of penetration and aspiration between different factor levels. SAS version 9.1 was used for all analyses and an α level of 0.05 was set for statistical significance.

Results

PAS as Function of Liquid Type, Delivery Method, and Bolus Volume

PAS scores differed significantly by 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, for larger versus small boluses, and for straw versus cup delivery. PAS scores for water ($M = 1.4$) differed significantly from those of skim milk ($M = 1.6$, $p = .03$), 2% milk ($M = 1.6$, $p = .0001$), and whole milk ($M = 1.8$, $p < .0001$). PAS scores for 20 ml ($M = 1.8$) differed significantly from 5 ml ($M = 1.5$, $p = .01$) and 10 ml ($M = 1.6$, $p = .01$). PAS scores as a function of liquid type, delivery method, and bolus volume collapsed across age and gender are shown in Table 2.

Occurrences of and Sensorimotor Response to Penetration and Aspiration

There were 462 episodes (19%) of penetration and 83 episodes (3%) of aspiration during the cohort's 2,432 total swallows. Eighty-three percent (63/76) and 28% (21/76) of the participants demonstrated penetration and silent aspiration, respectively, at some point in the testing. Eighty-five percent (123/145) and 61% (51/83) of penetration and aspiration episodes, respectively, did not elicit a sensorimotor response (i.e., throat clear and/or cough response). In other words, there was no attempt by the participant to clear the penetrated or aspirated liquid. Of note, endoscopic evaluation scores transient penetration, which occurs with the swallow, as a PAS 2. That is, no penetration is seen in the laryngeal vestibule after the swallow, so no sensorimotor response would be expected. Accordingly, PAS 2 was eliminated from the sensorimotor calculations. The number of aspiration episodes as a function of the number of participants is presented in Table 3. Observed PAS scores are summarized separately for each component of the testing condition in Table 4.

Odds Ratio of Penetration and Aspiration

Adjusted mean penetration and aspiration rates, as a function of predictor factors (i.e., liquid type, bolus volume, delivery method, and age), with the 95% confidence intervals are displayed in Table 5. The higher the fat content of a liquid, larger bolus volume and older age increased the risk of penetration. Specifically, milk increased the risk for penetration by at least 30% compared with water, with 31% for skim milk ($p = 0.049$), 54% for 2% milk ($p = 0.007$) and 59% for whole milk ($p = 0.001$). A bolus volume of 20 ml increased the risk of penetration by 33% compared to 5 ml ($p = 0.047$) and 10 ml ($p = 0.017$). Compared with 61- to 70-year olds, 71- to 80-year olds had a doubled risk for penetration ($p = 0.044$), and 81- to 90-year olds had an increased risk by 2.5 fold ($p = 0.008$). Delivery type showed no statistical significance on risk of penetration ($p = 0.062$). Similarly, higher fat content of a liquid and older age increased the risk of aspiration. Two percent milk and whole milk increased the risk for aspiration by 3.2 and 2.7 fold, respectively, compared with water. The aspiration risk increased by 6.7 fold in 81- to 90- year olds compared with 61- to 70-year olds. Larger bolus volumes tended to increase the risk of aspiration ($p = 0.068$). Delivery type did not appear to have any effect on risk of aspiration ($p = 0.409$).

Discussion

PAS scores as a function of liquid type (i.e., water; skim milk, 2% milk, and whole milk), bolus volume (i.e., 5, 10, 15, and 20 ml), and bolus delivery method (i.e., straw and cup) were evaluated during FEES in 76 older healthy volunteers. Penetration and aspiration were observed in 19% and 3% of participants' swallows, respectively. Twenty-eight percent (21/76) of the participants silently aspirated at some point in the study testing, and 61% of the total aspiration occurrences did not elicit a cough reflex. PAS scores varied as a function of liquid type, with milk yielding more severe PAS scores than water. PAS scores also varied as a function of bolus volume and delivery method, with 20 ml bolus volumes and straw delivery yielding more severe PAS scores than small boluses and cup delivery. The risk of penetration increased with skim, 2%, and whole milk versus water; with 20 ml versus 5 and 10 ml boluses; and with 7th versus 8th and 9th decades of life. Similarly, the risk of aspiration increased with 2% and whole milk versus water, with skim versus 2% milk, and with 7th versus 9th decade of life.

These findings of higher PAS scores on milk versus water agree with previous findings from our pilot studies. Clinically, the choice to use water or milk during FEES may be an important one, especially in patient populations (e.g., bedridden individuals) where the risk for aspiration pneumonia may be high. On the other hand, a few participants aspirated only water and not milk. Thus, these data suggest that testing both water and milk in clinical scenarios is prudent; however, if testing aspiration of liquids using only one liquid type, milk will likely provide the highest yield of aspiration and risk for aspiration pneumonia.

All milk types elicited significantly higher PAS scores than water; however, the highest was elicited by 2% milk, which may bear clinical significance. Logistic regression analyses yielded risks of aspiration that are approximately three times greater for 2% and whole milk compared to water and about 2 times greater for 2% versus skim milk. As we hypothesized, in general, the risk of penetration and aspiration increases with greater “milkiness” of the liquid administered. Thus, it appears that if a clinician needs to rule out aspiration in an individual at high risk for aspiration pneumonia, testing with milk is prudent and likely testing with 2% milk is the best choice.

Testing with milk only during FEES could lead to an overly restrictive diet recommendation. Most participants who aspirated milk did not aspirate water. Thus, for patients with a low risk of pneumonia, our results suggest that it is important to test water as well as milk, since the patient may not aspirate water even if they demonstrate aspiration on milk.

Bolus size was a significant main effect in this study; 20 ml elicited higher PAS scores than 5 and 10 ml in healthy adults. In a previous report, an average bolus size was approximately 21 ml in individuals 70-79 years old (9); thus, a 20 ml bolus is reasonable to expect a participant to be able to swallow. The risk of penetration also significantly increased with the 20 ml volume. Although all participants were instructed to swallow the entire amount in the cup in one swallow, several participants swallowed the 20 ml volumes in two swallows. Clinically, most professionals do not typically test with controlled bolus volumes; however, these findings are encouraging that if aspiration is seen on a larger bolus swallow, it may be eliminated with a smaller one.

Mean PAS scores were found to be significantly higher for straw versus cup drinking. Although straw drinking elicited higher PAS scores, neither penetration nor aspiration were statistically more likely for straw versus cup drinking. So it appears that bolus delivery method marginally influenced measured swallowing outcomes in this sample of healthy adults. However, in a sample with dysphagia, the risk of penetration and aspiration may be significantly higher for straw versus cup drinking. Thus, bolus delivery methods warrant future systematic investigation in cohorts with dysphagia.

These data in healthy normal adults should be interpreted cautiously for patients who present clinically with aspiration risk and complication. For example, one could generalize these findings to patients with dysphagia. However, replication of this study in such patients would be needed to validate that generalization. Furthermore, while it is logical to associate more severe PAS scores with greater negative health consequence (e.g., pneumonia), there are no current data to demonstrate that direct association.

We found that participants in the 8th and 9th decades of life were twice as likely to demonstrate penetration as those in the 7th decade of life. Further, individuals in their 9th decade of life were 7 times more likely to aspirate than individuals in their 7th decade. This seems to reflect the aging process in the oropharynx and hypopharynx (10, 11), which is likely more pronounced with increasing age.

The finding that 30% of this cohort silently aspirated replicates findings from the previous independent sample studies (12, 13) [in review]. But the aspirators did not typically consistently aspirate, as only 3% of the study swallows yielded silent aspiration. A possible clinical interpretation of these findings is that an *isolated* event of liquid aspiration during a FEES exam, in a patient with dysphagia older than 70 years, is within the range of normal and does not call for diet restrictions. However, clinical judgment should always be exercised relative to a patient's perceived risk of aspiration pneumonia and/or pulmonary health. Conversely, older adults who aspirate, although infrequently, may be at greater risk for community-acquired pneumonia or negative effects on the lungs. Even an isolated event of aspiration may provide a mechanism for direct transit of colonized pathogens (e.g., streptococci) from the oropharynx into the lungs.

Other researchers have demonstrated that FEES is more likely to identify penetration and aspiration than videofluoroscopic swallowing examinations in patient populations (1, 2, 4, 14), yet none have concurrently employed both techniques in the same sample of healthy adults. It is unknown if the higher prevalence of aspiration in healthy older adults can be confirmed with videofluoroscopic swallowing examinations.

A central question is whether all aspiration is bad in older adults. On the one hand, it may be important to identify healthy older adults who at risk for aspiration, considering that its sequelae (e.g. community-acquired pneumonia, malnutrition, weight-loss, and sarcopenia) are serious and can lead to functional decline and frailty. In that light, the most sensitive tool to detect aspiration (e.g., FEES) should be employed whether evaluating healthy adults or patients. On the other hand, if aspiration is benign, either FEES or videofluoroscopic swallowing examinations could be warranted, and greater sensitivity of one method versus another would be less pertinent. Currently, no data from longitudinal or cross-sectional studies exist to support or refute the association of aspiration with pneumonia in healthy older adults.

Conclusion

We found that varying bolus factors influence the outcomes of FEES. Milk elicited higher PAS scores and risk for penetration and aspiration compared to water test boluses in a sample of healthy older adults. Twenty ml bolus volumes yielded higher PAS scores and risk for penetration than 5 and 10 ml bolus volumes. Straw delivery yielded higher PAS scores than cup delivery. Lastly, healthy participants in the 9th decade of life had a higher risk of penetration and aspiration than participants in the 7th decade of life. Our findings underscore the importance of choosing optimal test factors of liquid type, bolus volume, and delivery methods during FEES, and that these choices could affect swallowing safety diagnoses and diet recommendations.

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Table 1

Penetration Aspiration Scale (5) Categorized According to Swallowing Status

Swallowing Status	PAS Score	Description
No Penetration or Aspiration	1	Material does not enter the airway
Penetration	2	Material enters the airway, remains above the vocal folds, and is ejected from the airway
	3	Material enters the airway, remains above the vocal folds, and is not ejected from the airway
	4	Material enters the airway, contacts the vocal folds, and is ejected from the airway
	5	Material enters the airway, contacts the vocal folds, and is not ejected from the airway
Aspiration	6	Material enters the airway, passes below the vocal folds, and is ejected into the larynx or out of the airway
	7	Material enters the airway, passes below the vocal folds, and is not ejected from the trachea despite effort
	8	Material enters the airway, passes below the vocal folds, and no effort is made to eject

Table 2

PAS Scores as a Function of Liquid Type, Delivery Method, and Bolus Volume

		Volume (ml)	PAS								
Liquid	**Delivery**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	***M (SE)***
Water	Straw	5	64	8	0	1	0	1	1	1	1.4 (0.1)
		10	66	7	1	0	1	0	1	0	1.3 (0.1)
		15	64	10	1	1	0	0	0	0	1.2 (0.1)
		20	63	11	1	0	0	0	1	0	1.3 (0.1)
	Cup	5	57	14	3	0	1	0	0	1	1.4 (0.1)
		10	64	10	0	0	1	0	0	1	1.3 (0.1)
		15	60	12	0	1	1	0	1	1	1.4 (0.1)
		20	62	12	0	1	0	0	0	1	1.3 (0.1)
Skim Milk	Straw	5	61	13	1	0	0	0	1	0	1.3 (0.1)
		10	54	11	7	2	1	0	1	0	1.5 (0.1)
		15	55	12	5	1	1	0	2	0	1.5 (0.1)
		20	57	9	3	0	2	0	1	4	1.8 (0.2)
	Cup	5	68	5	2	0	0	0	0	1	1.2 (0.1)
		10	62	8	2	1	1	0	1	1	1.4 (0.1)
		15	61	9	2	1	0	0	1	2	1.5 (0.2)
		20	56	13	2	1	1	0	0	2	1.5 (0.1)
2% Milk	Straw	5	57	10	3	0	5	0	0	1	1.6 (0.1)
		10	59	11	2	0	1	0	0	3	1.5(0.2)
		15	54	13	1	0	1	0	4	2	1.8 (0.2)
		20	54	12	4	0	1	0	2	3	1.8 (0.2)
	Cup	5	61	6	3	1	4	0	0	1	1.5 (0.1)
		10	62	8	2	0	1	0	0	3	1.5 (0.2)
		15	57	9	3	0	1	1	0	5	1.8 (0.2)
		20	51	10	5	0	3	0	3	2	1.9 (0.2)
Whole Milk	Straw	5	53	12	5	1	1	0	2	2	1.7 (0.2)
		10	55	15	4	0	0	0	1	1	1.5 (0.1)
		15	54	8	8	0	2	0	2	2	1.8 (0.2)
		20	53	9	7	0	0	1	1	5	1.9 (0.2)

Liquid	Delivery	Volume (ml)	PAS								*M (SE)*
			1	2	3	4	5	6	7	8	
	Cup	5	63	6	2	1	2	0	1	1	1.4 (0.1)
		10	62	7	5	1	0	0	0	1	1.4 (0.1)
		15	57	9	5	1	0	0	1	2	1.6 (0.2)
		20	56	8	7	1	1	0	1	2	1.6 (0.2)
Total			1882	317	96	16	33	3	29	51	1.5 (0.03)

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Table 3

Number of Aspiration Episodes as a Function of Number of Participants

Participants (*N*)	**Silent Aspiration Episodes**
9	1
4	2
3	3
3	4
1	5
1	8

Table 4

Summary of PAS Scores across Testing Conditions

Condition	Number of Swallows	*M (SE)*	Penetration (PAS 2-5)		Aspiration (PAS 6-8)		Silent Aspiration (PAS 8)	
			N (%) of Swallows	N (%) of Patients	% of Swallows	N (%) of Patients	N (%) of Swallows	N (%) of Patients
Liquid								
Water	608	1.40 (0.05)	98 (16)	17.8	10 (2)	1.6	5 (1)	0.8
Skim Milk	607	1.61 (0.07)	116 (19)	21.9	17 (3)	2.8	10 (2)	1.7
2% Milk	605	1.88 (0.10)	120 (20)	24.8	26 (4)	5.0	20 (3)	3.3
Whole Milk	607	1.81 (0.11)	128 (21)	25.4	28 (5)	4.3	16 (3)	2.6
Delivery								
Straw	1215	1.70 (0.08)	246 (20)	24.0	42 (3)	3.8	24 (2)	2.0
Cup	1212	1.65 (0.07)	216 (18)	20.9	37 (3)	3.1	27 (2)	2.0
Bolus Volume								
5 ml	608	1.54 (0.07)	110 (18)	20.4	13(2)	2.3	8 (1)	1.3
10 ml	608	1.56 (0.09)	110 (18)	20.4	11(2)	2.3	12 (2)	1.6
15 ml	606	1.74 (0.08)	118 (19)	23.8	26(4)	4.3	14 (2)	2.3
20 ml	605	1.85 (0.09)	124 (20)	25.3	29(5)	4.8	19 (3)	3.1

Table 5

Adjusted Mean Penetration and Aspiration Rates from the Logistic Regression Model

	Penetration			Aspiration		
	Rate (%)	**95% Confidence Limits**		**Rate (%)**	**95% Confidence Limits**	
Bolus Volume						
5ml	22.08	15.86	30.74	1.35	0.66	2.75
10ml	22.08	16	30.46	1.35	0.51	3.57
15ml	27	19.89	36.65	2.61	1.47	4.61
20ml	29.42	21.84	39.65	2.93	1.62	5.33
Delivery Type						
Cup	22.74	17	30.41	1.72	0.98	3.01
Straw	27.37	20.48	36.57	2.17	1.06	4.46
Liquid Type						
Water	18.64	13.06	26.6	0.98	0.48	1.99
Skim Milk	24.38	17.91	33.19	1.7	0.83	3.51
2% Milk	28.75	21.61	38.25	3.13	1.62	6.06
Whole Milk	29.63	21.52	40.8	2.68	1.35	5.31
Age Group						
60~69	14.41	8.34	24.88	0.7	0.19	2.51
70~79	29.58	18.78	46.58	2.19	1.14	4.2
>80	36.39	24.3	54.47	4.71	2.2	10.08