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ORIGINAL ARTICLE

Effect of Age, Sex, Bolus Volume, and Bolus Consistency on Whiteout Duration in Healthy Subjects During FEES

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Abstract

One of the major limitations of the fiberoptic endoscopic evaluation of swallowing (FEES) is related to the challenging application of temporal measures. Among them, Whiteout (WO) is due to pharyngeal and tongue base contraction and might be used as an estimation of the pharyngeal phase duration. The aims of this study were to evaluate the inter- and intrarater reliability of WO duration and to appraise the effects of age, sex, volume, and texture of the boluses on this temporal measurement. A total of 30 healthy volunteers were recruited. According to their age, the subjects were grouped into three different age groups. Each of them underwent FEES examination with different textures (liquid, semisolid, and solid) and volumes. FEES examinations were video recorded, processed with the software Daisy Viewer 2.0, which allowed the acquisition of 25 frames per second (s) and analyzed by three different raters in order to collect data on WO duration. A total of 863 swallowing acts were video recorded. Intra- and interrater reliability of WO duration were excellent. Both volume and bolus's texture significantly affected WO duration. In particular, WO duration was significantly shorter for the liquid texture than for the semisolid and solids ones. In addition, male subjects scored significantly higher values of WO duration. Finally, WO duration was significantly higher in seniors. WO duration seems to be a reliable temporal measure during FEES examination. WO duration seems to be affected by several factors such as age, sex, volume, and consistency.

Keywords Deglutition · Deglutition disorders · FEES · Whiteout

Introduction

Fiberoptic endoscopic evaluation of swallowing (FEES) is one of the gold standards for the assessment of dysphagia together with Videofluoroscopic Swallowing Study (VFSS) [1, 2]. FEES examination offers several benefits, such as no radiation exposure (allowing repeated examinations at frequent intervals) [3], minimal invasiveness [4], portability and inferior costs [5]. Nevertheless, one of the major limitations of this technique is related to the challenging application of temporal measures [6]. The latter is considered of key importance both in clinical practice and in research; for this reason, several authors investigated the duration of swallowing events during VFSS [7]. Temporal measures have been investigated by different authors also during FEES. In particular, Shaker et al. [8], measured the duration of maximal vocal fold adduction; Perlman and Van Daele [6] analyzed onset of arytenoid adduction and closure of the pharynx; Van Daele et al. [9] measured the duration of arytenoid adduction and whiteout (WO). More recently, Butler et al. [10] analyzed bolus dwell time in elderly. However, most of these studies were performed on a limited number of subjects and did not lead to the development of a standard in temporal measures assessment to be used in clinical practice.

Among FEES temporal measures, WO duration appeared to be the most consistently event seen [11] and

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was characterized by strong interrater and intrarater reliability [12]. It occurs when tongue base retracts and the mucosa of the pharynx gradually tightens enclosing the tip of the endoscope during pharyngeal muscles contraction [11]. Specifically, as the lateral pharyngeal walls medialize, the tongue base retracts and the epiglottis begins to invert, the closure of the pharynx produces a transient obscuration of the view by light being reflected back to the endoscope [6, 11]. WO can be defined as a phase of obscured view appreciable through FEES corresponding to the transit of the bolus through the pharynx.

Logemann et al. [11] demonstrated the onset of hyoid elevation (indicating the onset of the pharyngeal phase of the swallow), measured fluoroscopically, occurs only 0.06 s before the onset of the obscured image [11, 12]. Thus, WO onset could be considered an endoscopic rough measure for the beginning of the pharyngeal phase of swallowing, while its duration could be considered as an estimate of the pharyngeal phase duration [6, 11]. For this reason, WO duration might be a useful temporal measure to be applied in clinical practice and research. Only a few studies have analyzed WO duration in normal swallowing with diverging results [6, 9]. Perlman and Van Daele [6] evaluated oropharyngeal swallowing of liquids using videoendoscopic and ultrasound measures simultaneously in five female subjects and reported a mean WO duration of 469 ms. Van Daele et al. [9] analyzed the timing of swallow in four healthy subjects using electromyographic and endoscopic analysis and found a mean WO duration of 971 ± 181 ms. Although previous studies reported preliminary data on WO duration in a limited number of subjects, no data regarding the effect of age, sex, bolus volume, and bolus consistency on WO duration are available to date.

The aim of this study is to analyze the effect of the above-mentioned variables on WO duration in healthy subjects. A second aim is to replicate data on interrater and intrarater reliability of WO duration measure. We hypothesized that WO duration is a reliable and reproducible measure, which can be easily assessed by different investigators within various clinical settings after proper training. In addition, it is possible that WO duration could be related to volume and texture of boluses as well as to subject characteristics such as age and sex. The importance of this study lies in the fact that WO duration could be advantageously used to analyze the temporal features of the pharyngeal phase of swallowing, providing additional objective information on swallowing dynamics. The data arising from this research may also increase the diagnostic utility of FEES and allow comparability of studies conducted by independent institutions.

Materials and Methods

The present study was conducted in accordance with the Declaration of Helsinki and it was previously approved by the Institutional Review Board of our hospital. All the data were collected prospectively.

Participants

Thirty healthy volunteers (15 males and 15 females, mean age 45.1 years, age range 21–74) without symptoms or history of dysphagia were consecutively recruited. The subjects were selected among medical and speech-language pathology students, their relatives, and people attending the University of the Third Age. All the enrolled subjects met the following inclusion criteria: age between 18 and 74 years; Montreal Cognitive Assessment (MoCA) score of 26 or higher for subjects older than 65 years [13]; preserved reading skills; no medical history of voice, swallowing, gastroenterological, respiratory, neurologic, rheumatologic, metabolic, hematologic, or neoplastic disorders. In order to screen for potential comorbidities, each study participant was interviewed by a resident in otorhinolaryngology (ENT) and filled out a detailed medical history questionnaire. Subjects aged over 75 years were intentionally excluded from this study in order to reduce the risk of recruiting participants affected by primary presbyphagia [14, 15]. In order to evaluate the effect of age on WO duration, the cohort of subjects was divided into three different age groups: 10 young adults, 10 adults, and 10 seniors (Table 1). All the subjects received exhaustive explanations regarding aims and objectives of the research, FEES evaluation, and all the possible risks involved. The subjects were made aware of all their rights, including the right to abandon the study at any time. All the enrolled volunteers gave their written informed consent. Finally, the 3-oz Water Swallow test [16] was performed as a

Table 1 Demographic characteristics of the enrolled population of healthy subjects

Group (age range)	Mean age (years)	Gender	
		Male (*n*)	Female (*n*)
Young adults (21–24)	23.9 ± 3.1 (21–24)	5	5
Adults (25–64)	38.4 ± 4.5 (25–61)	5	5
Seniors (65–74)	73.0 ± 4.1 (65–74)	5	5
Total	45.1 ± 3.8 (21–74)	15	15

Three different age groups of subjects were identified: young adults (with an age range of 21–24 years), adults (with an age range of 25–64 years), and seniors (with an age range of 65–74 years). Mean ± standard deviation values for each of the three different age groups are reported. Ranges are reported in brackets

preliminary screening for dysphagia; none of the subjects failed this test.

Subjects Evaluation and Whiteout Measurement

A careful ENT physical examination and an endoscopic evaluation of the upper aero-digestive tract were performed in order to exclude both major head and neck pathologies and relevant anatomic and functional variations able to invalidate the analysis. FEES was then conducted by a senior Phoniatrician. For this purpose, a XION EF-N flexible endoscope with a diameter of 3.4 mm and a length of 320 mm (XION GmbH, Berlin, Germany) mounted on an EndoSTROB E camera (XION GmbH, Berlin, Germany) were used. The automatic light intensity control of the camera was disabled during the examinations. All the videos were processed using the software Daisy Viewer 2.0 (INVENTIS srl, Padua, Italy), which allowed the acquisition of 25 frames per second, therefore with a single frame lasting 40 ms. All the examinations were stored in an anonymous form in.AVI format on the system's hard drive, and saved on external memories as backup copies.

Each subject was seated on a comfortable chair, leaning back (between 75° and 90° approximately) with his arms on the armrests and keeping the head in neutral position to obtain the best posture for the examination. No local anesthetic drugs (e.g., lidocaine spray) were used in order not to alter pharyngo-laryngeal sensibility. The endoscope was introduced into the widest nasal cavity and kept at a level just inferior to the uvula to maximize the field of view, including the larynx, the glossoepiglottic valleculae, and the pyriform sinuses [11]. Food of different textures (thin liquid, semisolid, and solid) and volumes were provided during FEES examination to evaluate swallowing. Room-temperature water dyed with 5% methylene blue (10 mg/mL) was used for thin liquid trials, while room-temperature Crème Line vanilla pudding (Nutrisens Medical SAS, Francheville, France) was used for semisolid trials. For both consistencies, nine consecutive trials using preloaded syringes with gradually increasing volumes were performed (three trials with 5 mL, three trials with 10 mL, and three trials with 20 mL). The three consecutive trials of solid texture were performed with half an 8-gram dry biscuit (4 g per trial). For each subject, a total of 21 boluses were administered under FEES examination. All the subjects received the same instructions during the examination. They were advised to hold the bolus and swallow on command; holding bolus time was 5 s. Attention was paid during all the swallow trials not to retract the endoscope, thus avoiding WO related to velar contraction rather than pharyngeal and tongue base movements.

WO evaluation was conducted by three independent operators using the video files—one ENT resident (Examiner 1) and two speech-language pathologists (Examiner 2 and Examiner 3, both with over 5 years of experience in swallowing rehabilitation and FEES examinations)—in order to assess interrater reliability. None of the raters were involved in the FEES examination and all of them were blind to participants' data, since videos were stored in an anonymous form. Additionally, Examiner 1 repeated the measurements 2 weeks later in order to determine intrarater reliability; during the second evaluation, no information regarding the results of the prior measurements were provided.

In order to become familiar with the WO measurement, each examiner completed a preliminary 12-h training in frame-by-frame analysis under the supervision of a senior phoniatrician before beginning the study. In particular, the training consisted of 2 h of frontal teaching (performed by the senior phoniatrician) which aimed to provide the theory behind the WO and its measurement, and 10 h of practice in frame-by-frame analysis. The 10 h of practice was divided into 5 h dedicated to practicing solo (each examiner analyzed by himself a sample of 10 video recorded FEES examinations, different from those used in the study) and 5 h dedicated to in-group practicing. During this occasion, the three raters and the senior phoniatrician analyzed jointly the same 10 video-recorded FEES examinations in order to discuss their findings and to calibrate the judges. WO measurement was conducted only on actual bolus swallows, thus excluding from the analysis other swallowing acts (e.g., saliva swallows). For each WO video segment, the starting point of the frame counting was set at the first totally white endoscopic image or "*frame zero*." From this frame, the counting proceeded to the last frame or "*frame n*," in which not only the WO was lost but hypopharyngeal and laryngeal structures became again clearly visible; structures were defined clearly visible when it was possible to recognize an anatomic structure (pharyngeal wall, epiglottis, uvula, soft palate). In doubtful cases, a backward frame counting starting from *frame n* was also performed to verify the forward count. The duration of each WO event was easily calculated using the formula:

$$\mathrm{WO\,(ms)} = n \times 40$$

with n corresponding to the total number of frames, excluding *frame zero*. The swallowing acts during which a totally white image (*frame zero*) was not clearly identifiable due to various reasons (endoscope movements, head movements while swallowing, and bolus residues) were excluded from the analysis. Similarly, also the swallowing acts in which the end of WO (*frame n*) was not clearly detectable (secretions or bolus residues on the tip of the endoscope and incorrect patient posture) were discarded.

Only single swallows and the first swallow in case of multiple swallows were analyzed.

Statistical Analysis

Statistical tests were performed using the SPSS 23.0 statistical software (SPSS Inc., Chicago, IL). The Kolmogorov–Smirnov test was used to test the normality of the WO durations distribution among healthy volunteers. Since this test demonstrated that the distribution of WO durations was normal, parametric tests were used. Interrater and intrarater reliability were assessed using two-way random Intraclass Correlation Coefficient (ICC). Student's *t* test and Anova test with Tukey post hoc test were used to analyze the differences in WO duration according to the volume and texture of the swallowed bolus as well as to the subjects' characteristics such as age and sex.

Results

All subjects included in the study completed the full FEES protocol without any complications. No relevant signs of impaired swallowing safety or efficacy were found by the senior clinician conducting the examinations. The time required to complete FEES never exceeded 15 min. A total of 863 swallowing acts were video recorded. Sixty-one of them (7% of the swallows) were excluded because *frame 0* and/or *frame n* were not identifiable. All three examiners, who independently analyzed the recorded videos, agreed to exclude the same 61 swallowing acts. Among the remaining 802 swallowing acts, only the single swallows and the first swallow in case of multiple swallows were analyzed. Out of the 802 swallows, 221 were multiple swallows or clearing swallows and have not been analyzed; the resulting 581 swallowing acts were examined through frame-by-frame analysis. Results of intrarater and interrater reliability analysis are reported in Table 2. Both intrarater and interrater reliability were excellent, with ICC values ranging from 0.961 (range 0.951–0.971) to 0.992 (range 0.990–0.993).

The mean duration of WO measured in the group of 30 healthy subjects is reported in Table 3 and in Fig. 1. When considering all the subjects, the mean WO duration ± standard deviation (SD) for the liquid texture was 591 ± 113 ms. No significant difference in WO duration according to the volume of liquid were found on Anova test [$F(2, 248) = 0.710$, $p = 0.493$, $\varpi^2 = 0.01$]. The mean WO duration ± SD for the semisolid texture were 663 ± 90 ms. Significant differences in WO duration according to the volume of semisolid were found on Anova test [$F(2, 240) = 4.087$, $p = 0.018$, $\varpi^2 = 0.09$]. In particular, Tukey post hoc test demonstrated that WO duration with volumes of 5 mL was significantly shorter than WO duration with volumes of 20 mL ($p = 0.032$). Finally, the mean WO duration ± SD for the solid texture was 675 ± 83 ms for a 4 g solid bolus.

Anova test demonstrate a significant effect of bolus's texture on WO duration [$F(2, 580) = 9.674$, $p = 0.001$, $\varpi^2 = 0.11$]. In particular, WO duration was significantly shorter for liquids than for the semisolids (p values always < 0.001 for volumes of 5, 10, and 20 mL, respectively, on Tukey post hoc test). In addition, WO duration was significantly shorter for the liquid texture than for the solid one (p values always < 0.001 for volumes of 5, 10 and 20 mL of liquid vs 4 g cookie, respectively, on Tukey post hoc test). On the other hand, no significant differences among the WO duration for semisolid and solid textures were demonstrated (Table 4).

Regarding the effect of sex on WO duration, the Student's t-test revealed a significant difference in the distribution of WO duration for liquid, semisolid, and solid textures, in males and females (Table 5). In particular, male subjects scored significantly higher values in WO duration for 5 and 20 mL of liquid texture ($p = 0.030$ and $p = 0.001$, respectively), for 5 mL of semisolid texture ($p = 0.022$) and for 4 g of solid texture ($p = 0.002$).

In order to evaluate the effect of age on WO duration, the cohort of healthy subjects were divided into 3 different age groups (Table 1). The results of WO duration according to age is reported in Table 3. Significant differences in WO duration for the liquid texture with all volumes among the different age groups were demonstrated on Anova test [$F(2, 82) = 10.839$, $p = 0.001$, $\varpi^2 = 0.12$ for volumes of 5 mL; $F(2, 82) = 17.518$, $p = 0.001$, $\varpi^2 = 0.07$ for volumes of 10 mL; and $F(2, 82) = 10.817$, $p = 0.001$, $\varpi^2 = 0.09$ for volumes of 20 mL]. The results of post hoc analysis performed using Tukey test are reported in

Table 2 Intrarater and interrater reliability obtained using the two-way random Intraclass Correlation Coefficient (ICC). Interquartile ranges are reported in brackets

Interrater	Intrarater		
Rater 1 test–retest	Rater 1 versus rater 2	Rater 1 versus rater 3	Rater 2 versus rater 3
0.985 (0.98–0.987)	0.982 (0.980–0.984)	0.992 (0.990–0.993)	0.961 (0.951–0.971)

Table 3 Whiteout (WO) mean duration ± standard deviation (in milliseconds) in healthy subjects according to age

Group	Liquid trials			Semisolid trials			Solid trials
	5 mL	10 mL	20 mL	5 mL	10 mL	20 mL	4 g
Young adults	556 ± 102 (440–1040)	558 ± 81 (400–960)	559 ± 67 (440–880)	621 ± 83 (480–1000)	676 ± 91 (440–840)	679 ± 100 (360–1160)	670 ± 82 (480–1160)
Adults	571 ± 93 (400–1120)	588 ± 55 (440–1040)	592 ± 76 (400–960)	633 ± 80 (520–1040)	641 ± 94 (400–840)	661 ± 93 (400–1120)	680 ± 99 (520–1120)
Seniors	589 ± 124 (480–1320)	618 ± 91 (440–1000)	688 ± 136 (440–990)	675 ± 91 (440–1040)	687 ± 84 (400–880)	700 ± 56 (400–1120)	675 ± 69 (480–1160)
Total	572 ± 124 (400–1320)	588 ± 90 (400–1040)	613 ± 126 (400–990)	643 ± 91 (440–1040)	668 ± 91 (400–880)	680 ± 88 (360–1160)	675 ± 83 (480–1160)

Ranges are reported in brackets

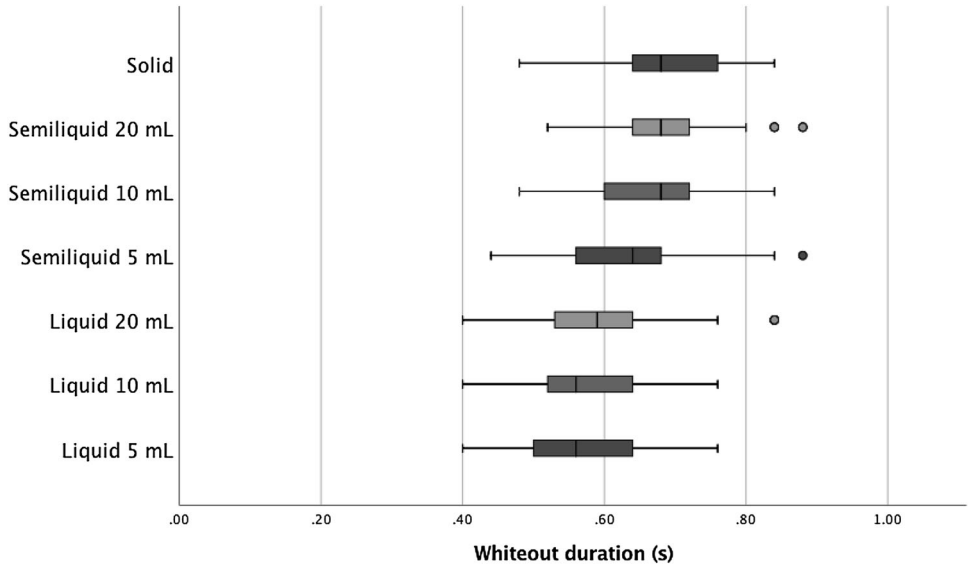

Fig. 1 Boxplots representing the whiteout (WO) duration according to volume and texture of boluses. Each box represents the interquartile (IQ) range which contains the middle 50% of the records. The lines extending from the left and right edge of the box represent the highest and lowest values of WO duration. The line across the box indicates the median, while the dots correspond to the cases with WO values more than three times the IQ range

Table 4 post hoc analysis on the effect of bolus' texture on WO duration is reported

Texture	Volume		Texture	Volume	*p*
Liquid	5 mL	vs	Semisolid	5 mL	0.001*
	10 mL	vs		10 mL	0.001*
	20 mL	vs		20 mL	0.001*
Liquid	5 mL	vs	Solid	4 g	0.001*
	10 mL	vs		4 g	0.001*
	20 mL	vs		4 g	0.001*
Semisolid	5 mL	vs	Solid	4 g	0.333
	10 mL	vs		4 g	0.982
	20 mL	vs		4 g	0.891

The *p* values obtained through the Tukey post hoc test are reported

*$p < 0.05$

Table 5 Effect of sex on whiteout (WO) duration

	Males	Females	*p*
Liquid			
5 mL	597 ± 127	557 ± 97	0.030*
10 mL	617 ± 84	559 ± 78	0.289
20 mL	658 ± 136	568 ± 91	0.001*
Semisolid			
5 mL	648 ± 68	638 ± 104	0.022*
10 mL	680 ± 81	656 ± 99	0.120
20 mL	690 ± 92	688 ± 84	0.842
Solid			
4 g	685 ± 64	665 ± 99	0.002*

The mean WO duration ± standard deviation (in milliseconds, ms) in healthy subjects for all trials and all textures are reported. The results of Student's *t* test comparison are also reported

*$p < 0.05$

Table 6 and revealed that WO duration was significantly higher in seniors than in young adults and in adults with all the volumes of liquids. Moreover, significant differences in the WO duration for the semisolid texture with volumes of 5 and 20 mL among the different age groups were demonstrated on Anova test [$F(2, 81) = 3.398$, $p = 0.038$, $\varpi^2 = 0.10$ for volumes of 5 mL; $F(2, 82) = 4.188$, $p = 0.018$, $\varpi^2 = 0.11$ for volumes of 20 mL]. In particular, Tukey post hoc test demonstrated that WO duration with volumes of 5 mL was significantly shorter in young adults than in seniors; in addition, the WO duration with volumes of 20 mL was significantly shorter in adults than in seniors and in young adults (see Table 6). On the other hand, no significant differences among the three age groups in the WO duration for solid texture were found on Anova test [$F(2, 87) = 0.090$, $p = 0.912$, $\varpi^2 = 0.12$].

Discussion

In the present study, the WO duration in a group of 30 healthy subjects was analyzed. The reported results appear interesting and provide additional information on the applicability of temporal measurements during FEES. The choice to measure the WO is related to the fact that it is considered to be the most consistent measurable event during FEES examination [11]. Therefore, our interest in this endoscopic phenomenon is strictly related to its potential utility for a better definition of the timing features of the pharyngeal phase of swallowing [6, 9]. However, it must be noted that WO probably does not represent the entire pharyngeal phase of swallow, consequently WO duration should be considered an imprecise measure of it.

Table 6 The effect of age on Whiteout (WO) duration is reported

Texture	Volume	Age groups comparison	ANOVA	Tukey post hoc
Liquid	5 mL	Young adults versus adults	0.001*	0.929
		Young adults versus seniors		0.001*
		Adults versus seniors		0.001*
	10 mL	Young adults versus adults	0.001*	0.746
		Young adults versus seniors		0.001*
		Adults versus seniors		0.001*
	20 mL	Young adults versus adults	0.001*	0.126
		Young adults versus seniors		0.001*
		Adults versus seniors		0.001*
Semisolid	5 mL	Young adults versus adults	0.038*	0.850
		Young adults versus seniors		0.040*
		Adults versus seniors		0.135
	10 mL	Young adults versus adults	0.121	NP
		Young adults versus seniors		
		Adults versus seniors		
	20 mL	Young adults versus adults	0.018*	0.040*
		Young adults versus seniors		0.998
		Adults versus seniors		0.034*
Solid	4 g	Young adults versus adults	0.912	NP
		Young adults versus seniors		
		Adults versus seniors		

The p values obtained through the ANOVA test with Tukey post hoc test (performed when requested) are reported

*$p < 0.05$

In a previous study using concurrent FEES and VFSS on eight normal subjects, it has been clearly shown that WO relationship with other temporal measures depends on volume; in addition, WO duration is shorter than hyoid bone elevation [11]. It is therefore very difficult to relate WO duration to swallow duration.

As far as the reliability of the WO duration, the results arising from the present study indicate both excellent interrater and intrarater reliability; it is possible that these high reliability scores could be related to the good visibility of this event during FEES [11]. Previous research [12] examining the agreement of two observers in identifying 12 selected normal oropharyngeal swallow events as visualized by videoendoscopy also found a 100% agreement in the identification of the onset of WO.

WO duration ranged from 556 ± 102 ms (for the 5 mL liquid bolus in the group of young adults) to 700 ± 56 ms (for the 20 mL semisolid bolus in the group of seniors). These results appear higher than those reported by Perlman et al. [6] (who found a mean WO duration of 469 ms in 5 females), and lower than those found by Van Daele et al. [9] (who reported a mean WO duration of 971 ± 181 ms in 4 males swallowing 10 ml of liquid). It must be noted that both authors used local anesthetic spray in order to reduce the discomfort during the insertion of the endoscope into the nose. It is possible that the local anesthesia may have affected the results of WO duration due to impaired sensation at the pharyngeal level. In our study, a total of 30 subjects were analyzed, anesthesia was not provided, and different textures and volumes were tested.

WO duration seemed to be related to the volume and texture of the bolus. In particular, WO duration was significantly shorter for liquid texture than for semisolid and solids ones. Moreover, an increase of WO duration with increasing volume was found. No previous data on the effect of bolus volume and consistencies on WO duration are available for comparison. Pharyngeal events duration has been analyzed using other techniques and those findings are compatible with the results of the present study. Reimers-Neils et al. [17] investigated the effects of six consistencies on measures of swallow duration using surface electromyographic (EMG) recordings of the submental and infrahyoid muscle complexes and found that total swallow duration increased significantly from liquids to thick pastes (from 1.334 s for the liquids to 3.036 for the thick pastes). Hoffman et al. [18] studied the effect of bolus volume on pharyngeal swallowing in 12 subjects using high resolution manometry (HRM) and reported that

velopharyngeal duration and total swallow duration increased with larger bolus volumes (0.907 s and 0.903 s for velopharyngeal duration and total swallow duration with 5 mL of water, respectively; 0.980 s and 1.086 s for velopharyngeal duration and total swallow duration with 20 mL of water, respectively). On the other hand, a recent review on temporary measures during VFSS does not found a clear influence of bolus volume on pharyngeal transit time (PTT), with a mean PTT ranging from 0.35 to 1.19 s [7].

In the present study, significant effects of age and sex were demonstrated on WO duration. In particular, women demonstrated lower values for WO duration than man for all the textures. In addition, significant differences in the WO duration across age groups were demonstrated. This finding is in agreement with the results of Perlman et al. [19] who reported a mean duration of pharyngeal pressure waveform from the onset of the tongue driving pressure to the return of the pharyngeal pressure wave to baseline of 569 ± 97 ms in normal subjects with a significant effect of both age and sex on the mean duration of this event. In particular, the duration of the waveform was significantly shorter in females and in younger subjects. With regards to the effect of age on WO duration, our results are in agreement with those of Logemann et al. [20] who used VFFS to study the temporal characteristics of oropharyngeal swallow in younger and older man, and reported that multiple duration measurements (base of tongue contact to pharyngeal wall, cricopharyngeal opening, and laryngeal closure) were prolonged in older subjects. Perlman et al. [19] reported that elderly subjects developed longer duration of oropharyngeal pressures (possibly related to the duration of WO) than younger subjects.

There are several limitations in this study. First, reliability was tested on three raters only and the effect of experience in FEES was not analyzed. Second, the number of recruited subjects per age and sex was limited, in addition, the choice of age boundaries might seem arbitrary even if it is similar to those identified in previous studies [21, 22]. Although no previous study analyzed WO duration in a larger number of normal subjects, the data here reported have to be considered as preliminary. Third, only three food consistency (thin liquid, semisolid, and solid) were considered, and data on other consistencies, such as nectar and honey-thickened liquids, are not available. Fourth, the intraobserver analysis was only done with one of the three raters and consequently the results of intrarater reliability should be considered with caution. Fifth, the sampling rate of the camera used in this study allowed the acquisition of 25 fps.

Finally, it is possible that WO duration might be affected by several variables such as fiberscopes of different diameter, different endoscopes or cameras, and different positions of the endoscope within the pharynx. Future studies should investigate the effects of all these variables.

Conclusions

In conclusion, WO duration seems to be a reliable temporal measure during FEES examination; preliminary data on the effect of age, sex, bolus volume. and consistency are in agreement with temporal measures using different techniques (HRM, VFSS, and EMG). Further studies that also include subjects with swallowing disorders should investigate the potential role of WO duration measurement in clinical practice.

Compliance with Ethical Standards

Conflict of interest Nothing to declare.

Research Involving Human Participants and/or Animals The present study was conducted in accordance with the Declaration of Helsinki, and it was previously approved by the Institutional Review Board of our hospital.

Informed Consent All the enrolled volunteers gave their written informed consent.

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