Dysphagia 20:149–156 (2005)
DOI: 10.1007/s00455-005-0008-y

Dysphagia

Timing of Pharyngeal and Upper Esophageal Sphincter Pressures as a Function of Normal and Effortful Swallowing in Young Healthy Adults

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Abstract. The effect of effortful swallow on pharyngeal pressure and UES relaxation onsets and durations was examined. Eighteen adults, nine males and nine females (mean age = 27.9 yr), participated. Timing of pharyngeal pressure and onset and duration of UES relaxation were measured across ten trials of normal and ten trials of effortful swallows. Results revealed that manometric timing measurements are consistent across trials. The first and second statistical analyses investigated the pharyngeal pressure and UES relaxation onsets and durations, respectively. Both analyses identified a significant interaction of swallow type (i.e., effortful vs. normal) by manometric sensor location ($p < 0.05$). Across normal and effortful swallows, UES relaxation preceded pharyngeal pressure onsets, yet the rate of change (or degree of delay) varied across the sensors. Furthermore, the effortful swallow elicited longer pharyngeal pressure and UES relaxation durations, yet the pressure duration measured in the upper pharynx was significantly longer than that measured lower in the pharynx. These findings offer insight as to the potential positive and negative influence of the effortful swallow on pharyngeal timing.

Key words: Pharyngeal — Upper esophageal sphincter — Effortful swallow — Pressure — Deglutition — Deglutition disorders.

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Swallowing maneuvers are often used to compensate for or rehabilitate oropharyngeal dysphagia. The effortful swallow is a maneuver that is frequently implemented when liquid or food residue is present in the pharynx after the swallow. The effortful swallow is believed to increase pharyngeal pressures thus pushing the bolus through the pharynx and the upper esophageal sphincter (UES), leaving less residue in the throat after the swallow. Dysphagia clinicians also use the effortful swallow as a rehabilitation technique for patients with presumed weak pharyngeal contraction. Therapeutic repetitions of swallowing with effort are aimed at eliciting greater contraction of pharyngeal muscles thus increasing the overall muscle strength over time.

Many texts on dysphagia describe the effortful swallow as a maneuver that will increase tongue base retraction and/or pharyngeal contraction [1–6]. However, a study by Bülow et al. [7] reported that no significant difference was found in inferior pharyngeal pressure between normal versus effortful swallowing. In fact, Bülow et al. reported that the mean peak pressure for effortful swallow was less than that for normal swallow in eight patients [8] and eight healthy participants [7]. Also, intrabolus pressure did not increase with the effortful swallow versus the normal swallow [9]. It should be noted that Bülow and colleagues reported pharyngeal pressures only at the level of the inferior constrictor, thus, pharyngeal pressure at the level of the base of tongue may still increase with the effortful swallow. Regardless, the application of the effortful swallowing maneuver increasing pharyngeal pressures is equivocal.

The effortful swallow may positively affect swallowing physiology in ways other than increased pharyngeal pressure. The effortful swallow may change the timing of the pharyngeal swallow and UES opening, i.e., it may prolong pharyngeal contraction and/or increase the duration of UES opening. Furthermore, the effortful swallow may elicit earlier pharyngeal pressures and/or UES opening potentially facilitating efficiency of bolus flow through the pharynx and into the esophagus.

Hind et al. [10] investigated the timing of oropharyngeal events during the effortful swallow using videofluoroscopy and reported that the effortful swallow elicited longer pharyngeal response, maximum anterior hyoid excursion, laryngeal vestibule closure, UES opening, and total swallowing duration. Given the constraints of taking visual measurements from videofluoroscopy, they were unable to determine the effects of pharyngeal pressure onsets and durations as a function of upper and lower pharynx, yet their study provides support for the hypothesis that the effortful swallow changes the physiologic timing of events created in the pharynx and UES.

Olsson et al. [11] investigated the relationship between UES relaxation duration and dysphagia and found that UES relaxation duration was significantly decreased in patients who experienced residue after the swallow, whereas the peak pharyngeal pressure was not significantly different. Thus, the manometric information that may be most important in identifying dysphagia lies in the timing of events not in peak pressures alone.

Kahrilas et al. [12] used manofluorography to investigate the effects of the Mendelsohn maneuver on pharyngeal pressure and UES relaxation. They reported that UES relaxation duration increased, whereas pharyngeal pressure remained the same with the Mendelsohn maneuver.

It is plausible that pharyngeal pressure onsets and durations produced during an effortful swallow vary according to the upper versus the lower pharynx. Peak pressure differences have been reported as a function of pharyngeal location. Olsson et al. [13] reported that in ten healthy participants less pharyngeal pressure was created at the level of the base of the tongue compared with the level of the inferior constrictor on a normal swallow. Furthermore, durational differences existed as a function of pharyngeal location. Duration of pressure at the tongue base was longer than that measured low in the pharynx. Thus, knowledge of pharyngeal pressure durations relative to pharyngeal location created with the effortful swallow may guide treatment. That is, if increased upper pharyngeal pressure duration is increased with the effortful swallow, an individual who is experiencing increased vallecular residue may best benefit from this technique, whereas an individual with pyriform sinus residue may not and vice versa.

Pharyngeal manometry has been used to measure pharyngeal pressures and/or timing of pharyngoesophageal events [13–16]. Many of these original pharyngeal manometry studies were investigated with a 4.6-mm-diameter catheter. The pharyngeal and UES pressures obtained from that catheter were later deemed to be elevated simply due to the catheter size. Salassa et al. [17] later posed catheter standards with a much smaller manometric diameter of approximately 2.1 mm. Using a smaller catheter, normative pharyngeal and UES pressure values and timing are needed. Pharyngeal manometry offers objective information to the standard dysphagia evaluation, thereby increasing our understanding of pharyngeal weakness versus decreased pharyngoesophageal coordination. Olsson et al. [18] demonstrated that using solid-state manometry improved diagnostic ability in assessing individuals with dysphagia. The authors concluded that solid-state manometry appreciates the pharyngeal and UES peak pressures and timing. The authors used the 4.6-mm catheter which has deterred many clinicians because of the size of the catheter to be passed transnasally and general technical challenges [19]. However, the 2.1-mm catheter, which has been available for many years, is a solution. The 2.1-mm catheter is easily passed transnasally without topical anesthetic with only mild discomfort to the patient.

Thus, in our study it was of interest to determine normative timing values of pharyngeal pressure and UES relaxation using a small manometric catheter that could be used more in clinical practice given its potential for objective measurement of timing deficits in individuals with dysphagia. Furthermore, it was of interest to determine the effects of the normal and effortful swallows on timing parameters of pharyngeal pressure and UES relaxation. Specifically, the research questions were (1) What is the timing of upper and lower pharyngeal pressures and UES relaxation onsets relative to submental surface electromyography onset? (2) Does the timing of upper and lower pharyngeal pressures and UES relaxation onsets change as a function of effortful swallow? (3) What is the duration of upper and lower pharyngeal pressure and UES relaxation for normal swallowing? and (4) Does the duration of upper and lower pharyngeal pressure and UES relaxation change as a function of effortful swallowing?

Methods

Participants

Eighteen adults served as participants (mean age = 27.9 yr, SD = 4.6). Participants were volunteers and reported no history of swallowing problems, speech disorders, voice problems, pulmonary disease, neurologic disease, or structural disorders determined via questionnaire. All participants were ambulatory and in good health. Informed consent was obtained from all research participants prior to initiating data collection; ethics approval was obtained from the University of Canterbury Ethics Board.

Apparatus

A Kay Elemetric Swallowing Workstation (Kay Elemetrics, Lincoln Park, NJ) was used to obtain concurrent manometric, surface electromyographic (sEMG), and videoendoscopic data. For the manometry, a 100-cm-long round catheter, 2.1 mm in diameter (Model CTS3 + emg, Gaeltec, Hackensack, NJ), similar to that described by Salassa et al. was used [17]. The catheter used solid-state, unidirectional, posteriorly oriented sensors spaced 3 cm between sensors one and two and 2.33 cm between sensors two and three. Pressures were measured in the upper esophageal sphincter, level of inferior constrictor, and upper pharynx with sensors one, two, and three, respectively. Digital 12-bit samples were obtained with a sampling frequency of 500 Hz and displayed in a −100–500-mmHg display window. The system software generated pressure waveforms as a function of time.

For the sEMG, single-channel sEMG was acquired with 5.4-cm silver chloride electrode triode patches (Uni-Patch, Wabasha, MN). Digital 12-bit samples were obtained with a sampling frequency of 500 Hz. The system software generated electromyographic waveforms as a function of time. The videoendoscopic imaging was time-locked with the manometric and sEMG waveforms, all of which were displayed on the same monitor.

Procedure

A sEMG triode patch was placed submentally between the thyroid notch and the anterior mandible, targeting suprahyoid and floor-of-mouth muscles. Participants were seated in front of the monitor for sEMG biofeedback and were instructed in the effortful swallow. Participants used the sEMG waveform as a biofeedback modality to master differentiation between normal and effortful swallows. Once the participant demonstrated the ability to produce an effortful swallow without the visual biofeedback, the procedure for placing the manometric catheter began. Effortful swallowing training took approximately 5 minutes.

Catheter calibration was conducted according to the manufacturer's specifications prior to data collection in each participant. A 3.4-mm fiberoptic endoscope was passed transnasally to obtain a superior view of the hypopharynx. Once endoscopic placement was assured, the manometric catheter was passed transnasally through the other naris, into the hypopharynx, and through the UES. Using a pull-through technique, the catheter was pulled back until the high-pressure zone of the UES was observed in the waveform of sensor one. A posterior orientation of sensors two and three at the levels of the inferior constrictor and base of tongue, respectively, was obtained and assured. The catheter was taped to the nose of the participant to minimize displacement. Catheter reorientation was done as needed; thus, catheter orientation for data collection remained consistent. Once the catheter was in place, the fiberoptic endoscope was removed for data collection. Participants were given about 5 minutes to get familiar with the setting and equipment before data collection began.

Two conditions were studied: normal and effortful saliva swallows. Ten repetitions of each condition were acquired from the participants in counterbalanced fashion. Thus, participants contributed 20 swallows each, yielding a total of 360 swallows for analyses. Participants were seated upright and were given 1 minute between each trial to assure time for saliva regeneration.

Manometric onsets were measured relative to submental sEMG. Thus, sEMG onset served as the zero point from which all pharyngeal pressure and UES relaxation onsets were measured for both normal and effortful swallowing. McConnel et al. [19] used first onset of the hyoid bone as the zero point to measure manometric pharyngeal points. Submental sEMG reflects the recruitment of the suprahyoid muscles resulting in hyolaryngeal elevation; thus, onset of sEMG was used since fluoroscopy was not used for this study. Furthermore, Doty and Bosma [20] demonstrated that the mylohyoid muscle, one of the suprahyoid muscles targeted with sEMG, was the first muscle activated in the start of a swallow.

The waveforms were also probed relative to pressure duration. Thus, the duration of the increased pharyngeal pressure on each of the pharyngeal sensors and decreased pressure on the UES sensor was measured for both normal and effortful swallows.

Manometric onsets were extracted from the pressure waveforms offline and measured in seconds. Onset of pharyngeal pressure was operationally defined as the point in time at which the waveform departed from the zero baseline with the swallow pressure peak. Likewise, onset of UES relaxation was operationally defined as the point in time at which the waveform departed from the resting tonic pressure and formed the characteristic M-wave. Duration of pharyngeal pressure was measured from the onset till the increased pressure returned to the zero baseline. Similarly, duration of UES relaxation was measured from the onset of pressure departure from the resting pressure baseline to the culmination of the M-wave where the pressure returned to the resting baseline.

Data Analysis

Two separate analyses of variance (ANOVA) were used to examine the effects of pharyngeal and UES pressure onsets and durations, respectively. Separate analyses were needed since sEMG served as the zero point for measurements with the onset data and was not used for the duration data.

Results

Pharyngeal Pressure and UES Relaxation Onset

A three-factor ANOVA was performed to investigate pharyngeal pressure onset, relative to sEMG onset, as a function of sensor location (i.e., upper pharynx, lower pharynx and UES), swallowing condition (i.e., normal vs. effortful), and trial. There was no significant effect of trial ($p = 0.42$), thus, trial was removed from the model, i.e., trial was not a significant effect in the model and did not predict onset. Accordingly, a two-factor mixed ANOVA was performed to determine if pressure onsets changed as a function of swallow type at each of the three sensors. Mean pharyngeal pressure onsets as a function of sensor location and swallowing condition collapsed across trial are presented in Table 1. Significant main effects for sensor location [$F(2,36) = 332.65$, $p < 0.0001$] and swallowing condition [$F(1,18) = 56.04$, $p < 0.0001$] were found. A significant interaction of sensor location by swallowing condition was also found [$F(2,36) = 4.15$, $p < 0.024$].

Difference of least square means was undertaken to examine the significant interaction. The interaction is shown in Figure 1. Onsets for effortful swallows occurred significantly later than onsets for normal swallows at all sensors ($p = 0.04$, $p < 0.0001$, and $p < 0.0001$, respectively). In general, the UES initiated its onset first, followed by upper and then lower pharyngeal pressures relative to submental sEMG onset on both swallowing conditions, yet the effortful swallow elicited a delay in all pressure and relaxation onsets. The interaction is explained by the fact that although all the sensor locations demonstrated delayed onsets with the effortful swallow, the rate of change (or degree of delay) varied across the three sensors.

Pharyngeal Pressure and UES Relaxation Duration

A three-factor ANOVA was performed to determine if pressure durations changed as a function of sensor location (i.e., upper pharynx, lower pharynx, and UES), swallowing condition (i.e., normal vs. effortful), and trial. There was no significant effect of trial ($p = 0.10$), thus, trial was removed from the model, i.e., trial was not a significant effect in the model and did not predict onset. Accordingly a two-factor mixed ANOVA was performed to determine if pressure durations changed as a function of swallow type at each of the three sensors. Mean pharyngeal pressure durations as a function of sensor location and swallowing condition collapsed across trial are presented in Table 2. Significant main effects for sensor location [$F(2,36) = 161.08$, $p < 0.0001$] and swallowing condition [$F(1,18) = 163.75$, $p < 0.001$] were found. A significant interaction of sensor location by swallowing condition was also found [$F(2,36) = 7.76$, $p < 0.0001$].

Difference of least square means was undertaken to examine the significant interaction. The interaction is shown in Figure 2. Durations were significantly longer for effortful swallows vs. normal swallows at all sensors ($p < 0.0001$, $p < 0.0001$, and $p = 0.001$, respectively). In general, the duration of pharyngeal pressure was longer for the effortful versus normal swallows. Again, the interaction is explained in that the amount of increase in effortful vs. normal swallow duration varied across the three sensors. Two additional comparisons were conducted to compare the pressure durations at the upper and lower pharynx for the effortful vs. normal swallows. Pressure durations were significantly longer for the upper vs. the lower pharynx on the effortful ($p = 0.002$) but not the normal ($p = 0.32$), i.e., the effortful swallow generated longer upper vs. lower pharyngeal pressures.

Table 1. Mean pharyngeal and UES pressure onset relative to SEMG onset as a function of manometric sensor location and swallowing condition (s)

	Swallow condition	
	Normal	Effortful
Upper pharyngeal	0.43 (0.03)	0.48 (0.04)
Lower pharyngeal	0.63 (0.04)	0.74 (0.05)
UES	0.28 (0.02)	0.40 (0.05)

Standard error of the means are presented in parentheses.

Discussion

This study revealed significant effects of swallowing condition (i.e., effortful vs. normal) on the onsets and durations of the upper and lower pharyngeal pressure and UES relaxation. Specifically, effortful swallows elicited a delayed onset of pharyngeal pressure and UES relaxation compared with normal swallows. However, the effortful swallow elicited longer pharyngeal pressure and UES relaxation.

Manometric evaluation of the timing of pharyngeal and UES events of normal swallowing revealed that the onset of UES relaxation occurred before the onset of upper and lower pharyngeal pressures relative to sEMG onset. In addition, the duration of upper vs. lower pharyngeal pressure was not statistically different for the normal swallow but was statistically significant for the effortful swallow. Thus, although the upper pharyngeal pressure onset occurred before the lower pharyngeal pressure onset, duration of the pressure did not change as a function of the area of the pharynx (i.e., upper vs. lower pharynx) with normal swallows. Effortful swallows, however, generated increased pharyngeal pressure durations in the pharynx compared with normal swallows, and upper pharyngeal pressure duration was significantly longer than lower pharyngeal pressure duration.

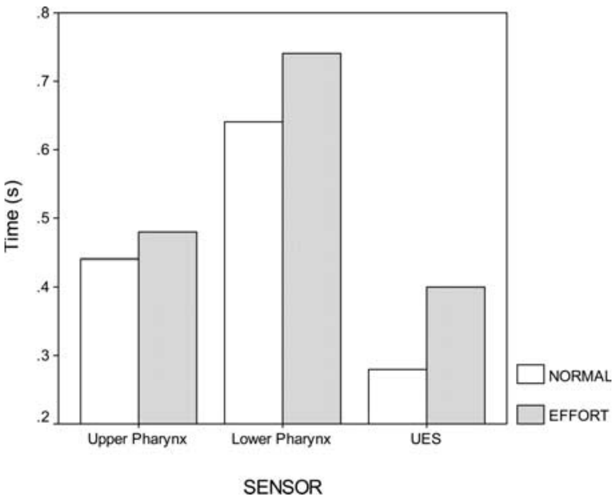

Fig. 1. Mean pharyngeal pressure onset as a function of swallow type and sensor location.

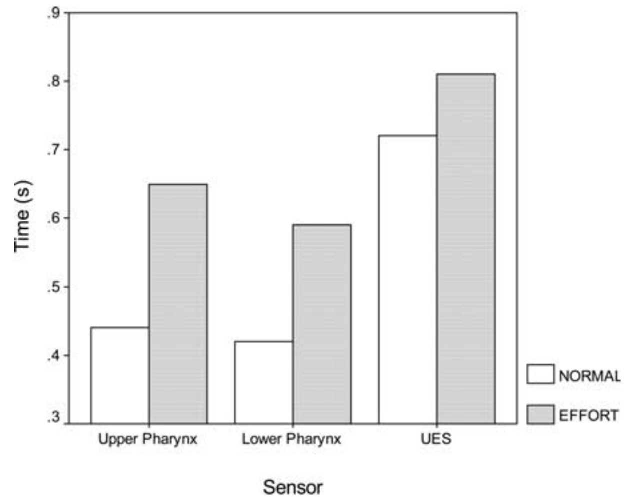

Fig. 2. Mean pharyngeal pressure duration as a function of swallow type and sensor location.

The effortful swallow is typically thought of and used in terms of its effect on pharyngeal pressure generation; however, the way in which effortful swallow affects the timing of swallowing may be equally or more important. The finding that the effortful swallow elicited a delayed onset of pharyngeal and UES events compared with that of the normal swallow has an impact on how clinicians use the compensatory technique of effortful swallow. From these manometric timing data, it appears that the effortful swallow may be contraindicated in an individual with a delayed pharyngeal response and used primarily with individuals with pharyngeal weakness only.

The effortful swallow elicited prolonged durations of pharyngeal pressure and UES relaxation. This increased duration of pharyngeal pressure and UES relaxation may facilitate pharyngeal clearing in an individual with increased residue at the level of the valleculae, pyriform sinuses, or just diffusely throughout the hypopharynx. Maintenance of UES relaxation/opening has also been demonstrated with the Mendelsohn maneuver [12]; however, in the Mendelsohn maneuver, pharyngeal contraction (i.e., base of tongue to posterior pharyngeal wall approximation) did not change as a function of maneuver. Kahrilas et al. [12] reported that the UES opening was maintained for approximately 0.56 ± 0.06 s with the Mendelsohn maneuver on a 1-ml bolus swallow, whereas the current study found that UES relaxation was maintained for 0.81 ± 0.05 s with the effortful swallow (dry swallow), and pharyngeal pressure was maintained significantly longer as well. Although it is difficult to compare across studies with varying measurement techniques, it is possible that the effortful swallow maneuver may be more appropriate for individuals with difficulty clearing a bolus from their pharynx. However, the UES relaxation differences need to be systematically measured within subjects across both effortful and Mendelsohn swallows to identify which swallow technique facilitates the longest UES relaxation.

Kahrilas et al. [21] used a slightly larger manometric catheter compared with the catheter used in the current study (3×5 mm, 2.1-mm catheter). With regard to UES relaxation, the larger-catheter's outer diameter used in the Kahrilas et al. study may simply take up more space within the UES, thus, not providing the potential for the UES to stay off the sensors longer. A smaller catheter, like that used in the current study, is preferred for several reasons. First, a smaller catheter allows for greater patient/participant comfort. Second, a smaller catheter presumably allows for a more accurate measurement of UES relaxation since the catheter does not occupy as much UES diameter as a larger catheter, thus artificially inflating the measured pharyngeal pressure or decreasing the measured UES relaxation duration.

The finding of increased pharyngeal pressure duration contradicts that previously reported by Bülow et al. [9]. They reported that pharyngeal pressure at the level of the inferior constrictor did not change as a function of effortful swallow in eight patients with dysphagia. However, five major differences exist between the two studies. First, the current study was on individuals with normal swallowing. Second, Bülow et al. evaluated pressures, whereas we measured duration of pressures. Third, they used the larger, older 4.6-mm-outer-diameter

Table 2. Mean pharyngeal and UES pressure durations as a function of manometric sensor location and swallowing condition (s)

	Swallow condition	
	Normal	Effortful
Upper pharyngeal	0.44 (0.03)	0.65 (0.04)
Lower pharyngeal	0.42 (0.05)	0.60 (0.04)
UES	0.73 (0.04)	0.81 (0.05)

Standard error of the means are presented in parentheses.

catheter. Fourth, they instructed the participants only in how to do the effortful swallow. They did not verify that the participants were indeed performing the effortful swallow. In the current study, the effortful swallow was taught and verified with sEMG biofeedback in a 5-minute training session. Fifth, Bülow et al. described the effortful swallow as such: "swallow very hard while squeezing the tongue in an upward–backward motion toward the soft palate" [9, p. 198]. The cue to push the tongue upward and backward is not a cue typically used to teach the effortful swallow.

The finding of increased upper vs. lower pharyngeal pressure durations on the effortful swallow is in agreement with that reported by Olsson et al. [22]. Using the larger 4.6-mm-outer-diameter catheter, they reported that the duration of tongue base to pharyngeal wall pressure was longer than that recorded at the lower pharynx. Thus, evidence increases that the effortful swallow will create longer pharyngeal pressure and presumably longer bolus driving forces to propel the bolus inferiorly through the hypopharynx.

The parameter of UES duration is an important variable to be studied to obtain normative data with the smaller 2.1-mm catheter and because decreased duration of UES relaxation has been associated with increased residue after the swallow. Using a 4.6-mm catheter, Olsson et al. [11] reported that individuals with pharyngeal residue after the swallow demonstrated a shorter UES relaxation duration. Thus, the current study provided data on UES relaxation duration in a small sample of young adults and also demonstrated that the effortful swallow increased the duration of the UES relaxation. Although Hind et al. [10] used videofluoroscopy to assess UES opening, they also reported that the effortful swallow resulted in increased UES duration compared with normal swallowing in middle-aged and older adults. It would have been interesting to compare the duration they measured via videofluoroscopy and the duration measured in the current study via manometry; however, mean data were not provided in that article. However, two different studies using two different technologies concur that the effortful swallow is a maneuver that increases UES duration and may be used by individuals who demonstrate residue after the swallow facilitating bolus flow through the UES thus decreasing risk for aspiration.

Investigation of the timing relation of UES relaxation to pharyngeal pressure in the normal swallow is also of benefit for future comparison to individuals with dysphagia. Manometry offers an objective way to determine UES relaxation onset, upper and lower pharyngeal pressure onset, and each of these event's timing relation to each other. The current study reports that UES relaxation occurred 0.15 s before upper pharyngeal pressure onset. This finding is consistent with that reported by others [16,21]. Thus, although catheter size and techniques varied across the studies, consensus exists that suprahyoid activity precedes UES relaxation followed by upper then lower pharyngeal pressures. This sequencing of UES and pharyngeal onsets may serve as comparison to individuals with dysphagia.

As an adjunct to the results discussed thus far, it should be noted that suprahyoid activity onset preceded UES relaxation by 0.28 s in the current study. McConnel et al. [16] used the first motion of the hyoid, as determined fluoroscopically, to determine the start of the swallow and reported a similar UES opening onset of 0.30 s (cf. 0.28 s) that succeeded hyoid excursion onset. Thus, it appears that one may use videofluoroscopic detection of hyoid motion or sEMG of suprahyoid activity as the start of the swallow to serve as the zero point from which to reliably measure the UES and pharyngeal events that follow.

Of note in this study is the use of saliva swallows as opposed to bolus swallows. Although the amount of saliva varies across participants and/or gender (e.g., 1.19 ml in men vs. 0.98 in women [23]), saliva swallows were chosen in this investigation for two reasons. First, in dysphagia rehabilitation, effortful swallows are typically implemented on saliva and not bolus swallows. Second, pilot data on normal saliva swallows are needed for comparison with future studies using patients with dysphagia. Patients with dysphagia may contribute saliva swallows for manometric analysis without increasing their risk for aspiration as that which is posed if bolus swallows are required. In addition, when an investigator implements bolus swallows it is inaccurate to assume that one is administering a controlled bolus volume because the delivered bolus volume mixes with the saliva already present in the oral cavity, i.e., even controlled bolus swallows are not truly controlled because of the contribution of baseline oral cavity saliva. Thus, saliva swallows were the desired bolus for studying the effortful vs. normal swallow and to contribute to a normative database for future comparison with individuals with dysphagia.

Future manometric research of normal swallowing should incorporate older participants since the incidence of dysphagia in the geriatric population is much higher than in young adults. This pilot study of normal vs. effortful swallows in young adults has demonstrated that pharyngeal and UES pressure durational changes do exist across the two conditions and warrant comprehensive investigation with older participants.

Conclusions

This study used a 2.1-mm manometric catheter to determine the timing differences of pharyngeal pressure and UES relaxation between two different swallowing conditions, normal and effortful swallow, in 18 young healthy adults. The effortful swallow elicited longer pharyngeal pressure and UES relaxation compared with a normal swallow. However, the effortful swallow resulted in delayed onset of UES relaxation and pharyngeal pressure compared with the normal swallow. Thus, the effortful swallow may be an indicated maneuver in an individual who has decreased hyolaryngeal excursion and pharyngeal pressure resulting in residue after the swallow and contraindicated in an individual who demonstrates those findings along with a delay in pharyngeal response. However, as with all maneuvers, each individual must be evaluated independently for the appropriateness of the maneuver.

This study also provided data from individuals with normal swallowing on UES relaxation and pharyngeal pressure onsets and durations with a small 2.1-mm catheter. A 2.1-mm manometric catheter with solid-state, posteriorly oriented sensors is well tolerated by individuals without need for topical anesthetic. Given the ease of use and objective information obtained from a 2.1-mm catheter, it is realistic to expect more frequent use of pharyngeal manometry in the clinical setting to objectively determine the nature of an individual's dysphagia. Thus, normative data of pharyngeal pressure and UES relaxation timing and intensity is needed on both young and older adults to serve as comparison to data obtained from individuals with dysphagia.

Acknowledgments. We would like to acknowledge the support of Bill Roche and the financial support of St. Joseph's Medical Center Grant Funds, Paterson, NJ, USA.

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