Manometric Measures Of Head Rotation And Chin Tuck In Healthy Participants

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Abstract:
The primary aim of this study was to investigate the immediate effects of partial versus complete head rotation and chin tuck on pharyngeal swallowing pressures and durations in the pharynx and UES of normal, healthy adults. Ten individuals (3 men and 7 women; age range 54–76 years) served as participants. Solid-state intraluminal manometry was performed with the participants in the upright position while performing swallows with the head in the normal position, head rotated (partial and complete), chin tucked, and chin down. A cervical range of motion (CROM) inclinometer was used to accurately measure the degree of head rotation and chin tuck. The CROM inclinometer has not been used before so this is the first study to our knowledge to quantify degree of head rotation and chin tuck. Manometric data derived from these healthy participants indicate both partial and complete head rotations can increase the duration of UES relaxation and decrease UES residual pressure. Chin tuck may be effective in increasing durations in the upper pharynx. Partial chin tuck (chin down) decreases UES residual pressure. Complete head rotation and chin tuck provide more overall benefit than partial maneuvers. However, for patients with limited head and neck mobility, partial posture changes impact the pharynx in similar ways and may provide clinically meaningful benefits. Additional research on patient populations is warranted.

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Introduction

Solid-state intraluminal manometry has been available since approximately 1985 to assess pharyngeal and esophageal motility function. While manometry is not a novel diagnostic tool for dysphagia, data defining ''normal'' swallowing function are still emerging. A number of compensatory and rehabilitative strategies have been developed to facilitate and improve swallowing function in patient populations, and there are few data that define the effects of those techniques on neurophysiological measures of a healthy swallowing mechanism. Two such maneuvers are head rotation and chin tuck.

Research in patient populations suggests that head rotation causes the bolus to lateralize away from the direction of head rotation [1, 2]. Head rotation has also been reported to facilitate the opening of the upper esophageal sphincter (UES) by posturally providing external pull on the cricopharyngeus muscle, the bulk muscle of the UES [1, 2]. For individuals with a smaller UES opening, head rotation may decrease the buildup of residue in the pyriform sinuses. For patients with delayed pharyngeal swallow onset, chin tuck is often the first compensatory strategy used [3]. Chin tuck has been used in head and neck cancer and neurogenic patients who exhibit poor airway protection and delayed initiation of swallow [4, 5]. According to Logemann [6], it can effectively eliminate aspiration over 50 % of the time.

While it has been observed that anatomical changes resulting from head rotation and chin tuck posture improve bolus flow and swallowing efficiency, results are not uniform across populations. More data on normal, healthy participants are needed to define the specific effects of the maneuvers on swallowing physiology. In particular, data are needed from using manometric measures, as pharyngeal and cricopharyngeal pressures may account for differences in bolus flow observed in patients in video fluoroscopic study (VFSS).

In the mid-1990s, DeVault [12] provided normative UES relaxation data and suggested that UES relaxation was normal when residual pressure was \6.7 mmHg. Takasaki et al. [11] recently reported higher UES resting pressure when the head was turned toward the catheter side ($p = 0.0001$) and lower UES resting pressure when the head was turned toward the opposite side ($p = 0.0001$) in 18 young male participants. McCulloch et al. [8] recently reported pressure and duration effects in the UES with head rotation and chin tuck. They utilized high-resolution manometry to investigate pressures across the pharynx with an emphasis on the velopharynx, tongue base, and UES. Their study added important findings to the literature about upper pharyngeal pressures and UES relaxation and compared their results with those of previous studies that used conventional manometry [3, 9, 10].

One aspect that has not been investigated is the degree of head rotation and chin tuck that is necessary to produce alterations in pharyngeal and UES pressures. In other words, how much of a head rotation or chin tuck is necessary to impact swallowing pressures and alter bolus flow? Some patients, due to neck injury or other problems, cannot move their head completely—as traditionally prescribed for successful implementation of these strategies. Other times, patients simply do not rotate or tuck as much as prescribed during assessment. Therefore, it seems prudent to measure the degree of head rotation and chin tuck to determine the impact that the degree of posturing has on pharyngeal pressures. Should pharyngeal pressures be impacted in a similar manner with partial changes in posturing in normal controls, additional research using videomanometry on patients would be warranted to explore pressure changes and bolus flow.

The objective of this investigation was to determine the effects of partial and complete head rotation and chin tuck on pharyngeal swallowing pressures, pressure durations, contraction onset time, and UES residual pressure and relaxation in healthy individuals.

Methods

Equipment

Data were collected using a 4.6-mm manometry catheter (Fig. 1) with one respiratory sensor and seven solid-state pressure transducers. The two proximal pressure transducers were standard microtransducers (Konigsberg Instruments, Inc., Pasadena, CA), with a single recording site oriented radially to measure 120°. The two distal transducers (Konigsberg Instruments) were circumferential, allowing 360° measurements. The volumetric compliance was 7 9 10^{-6} mm^3/mmHg, and the rate in the increase in pressure was over 2,000 mmHg/s. The analog signal was digitized by a Polygraph A/D converter. The software used was the Polygram Upper-GI Edition by Gastrosoft Inc./Medtronic (Synectics, Chicago, IL). All pressure values were expressed in millimeters of mercury (1.0 mmHg = 133 N/m^2, 7.5 mmHg = 1 kPa, 50 mmHg = 68 cmH_2O). The system was calibrated at 0 and at 50 mmHg. The calibration was done at 37 °C. All values given refer to atmospheric pressure. Range of motion of the head was measured using the cervical range-of-motion instrument (CROM) by Isokinetics (De Queen, AR), a detailed inclinometer strapped to the patient's head during head positioning to measure degree of head rotation and chin tuck across swallows (Fig. 2).

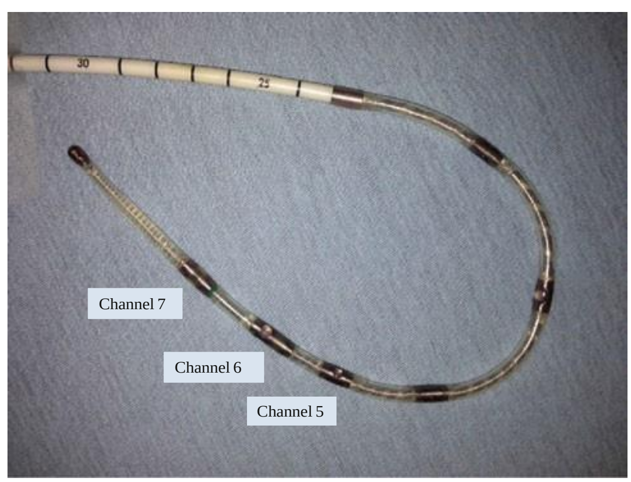

Fig. 1 4.6-mm Manometry catheter used to collect data

Fig. 2 CROM inclinometer

All participants fasted for 6 h before the study. Participants were seated upright, and each was given instructions 15 min before the procedure was initiated.

Data Collection

All procedures were approved by the Institutional Review Board for studies involving human subjects at the University of Arkansas for Medical Sciences (UAMS) Medical Center, and all data were collected at the UAMS Medical Center. One group of subjects was examined in this investigation. Initially, 11 research participants were recruited; one was disqualified during manometric screening for having an esophageal motility disorder. Thus, ten healthy individuals (3 males and 7 females, mean age = 61.2 years, range 54–76 years) participated in this study. Participants reported, via questionnaire, no history of swallowing problems, voice problems, speech disorders, pulmonary dysfunction, structural disorders, neurologic disorders, or any disorders of the gastrointestinal tract. All participants signed a written consent form.

Topical viscous 2 % lidocaine hydrochloride was applied to the right nostril with a cotton swab and the manometric catheter was passed through it. Participants were screened for abnormalities of the esophagus and LES. After esophageal dysphagia was ruled out, the main study protocol was initiated. Only three of the seven manometric sensors were used for the main protocol: Channels 5, 6, and 7. There was 2 cm between Channels 5 and 6 and 3 cm between Channels 6 and 7. Channel 5 rested approximately even with the valleculae region and the superior aspect of the epiglottis, Channel 6 rested at the pyriform sinus region, and Channel 7 rested within the UES. The tip of the catheter was located in the proximal esophagus. To ensure that Channel 7 was in the upper portion of the high-pressure zone of the UES, a pull-through technique was used wherein Channel 7 was pushed through the high-pressure zone and then pulled back through to create a high-pressure zone profile. Channel 7 was held in the upper region of the high-pressure zone defined by manometric placement. During swallowing, laryngeal elevation moves the UES in a cranial direction so it was essential to keep the sensor in the superior aspect of the high-pressure zone. When the catheter was positioned correctly in the cranial part of the UES, a characteristic M-shaped manometric wave appeared during swallowing. The M-shaped waveform represents an initial increase in pressure due to laryngeal elevation and the consequent high-pressure zone of the UES. The peak pressure is followed by a sudden decrease in pressure caused by UES relaxation. There is a final increase in pressure due to the contraction of the UES before the larynx descends after the swallow [13].

Each participant was instructed to swallow three 3-ml boluses of thin liquid (water) via syringe under the following randomly ordered conditions: (A) head in neutral position, (B) head rotated 45° to the right, (C) head rotated 90° to the right, (D) head rotated 45° to the left, (E) head rotated 90° to the left, (F) chin down, and (G) chin tuck. The CROM inclinometer was utilized to ensure proper positioning of the head for each swallow (i.e., 45° and 90° to the left and right, 30° for the chin down, and 50° for the chin tuck). After each swallow, the patient was instructed to return the head to the neutral position.

Biomechanical Assessment

Manometric data were displayed to the researchers but not to the participant during data collection. All manometric measurements were interpreted by two gastroenterologists to determine interobserver and intraobserver reliability. All values were means of three swallows repeated for every head position for every participant. Five variables were analyzed: (1) peak pressures (mmHg) in Channels 5 and 6, (2) contraction onset (ms) in Channels 5 and 6, (3) duration of contraction (ms) in Channels 5 and 6, (4) duration of UES relaxation in Channel 7, and (5) UES residual pressure in Channel 7 (see Fig. 3 for manometric reference points for all definitions). Peak pressure (mmHg) is defined as the apex of the waveform during the clearance phase of the pharyngeal swallow. Contraction onset was defined as the time (ms) between the initiation of peristaltic contraction and the peak pressure at the level of the superior

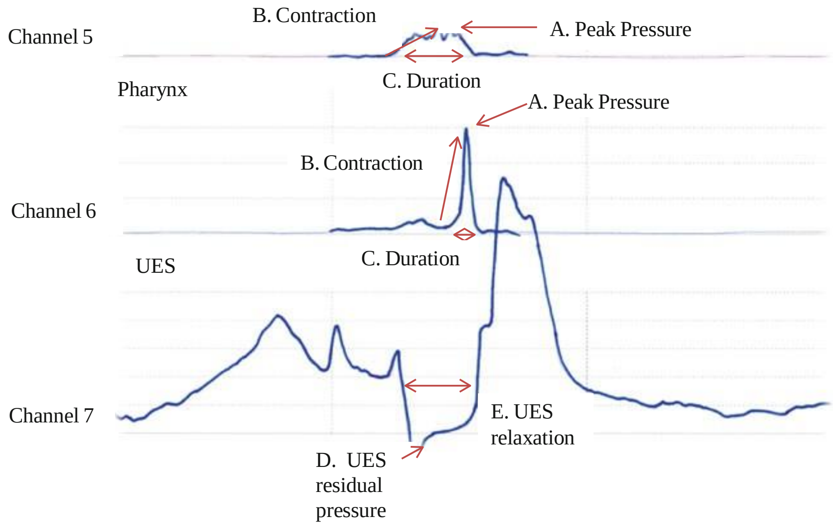

Fig. 3 (*A*) Peak pressure (mmHg) in channels 5 and 6: apex of the waveform during the clearance phase of the pharyngeal swallow. (*B*) Contraction (ms) in channels 5 and 6: time between the initiation of peristaltic contraction and peak pressure at the superior pharyngeal constrictor muscle. (*C*) Duration (ms) in channels 5 and 6: time between contraction onset and offset. (*D*) UES residual pressure (mmHg) in channel 7: remaining pressure when UES is completely relaxed during the swallow. (*E*) UES relaxation (ms) in channel 7: time between 50 % reduced UES resting pressure and 50 % resumption of UES resting pressure via the *M*-shaped waveform

pharyngeal constrictor muscle in Channels 5 and 6. Duration of pharyngeal contraction (ms) was defined as the period of time between the contraction onset time and offset time in Channels 5 and 6. Duration of UES relaxation was defined as the time (ms) between 50 % reduced UES resting pressure and 50 % resumption of UES resting pressure via the M-shaped waveform in Channel 7. UES residual pressure (mmHg) was defined as the remaining pressure (mmHg) when the UES is completely relaxed during the swallow.

The catheter was generally well tolerated and no examination had to be interrupted due to discomfort. No overt signs of aspiration were observed during examinations.

Data Analysis

For all analyses, an initial alpha (a) level of 0.05 was adopted. Because of the seven head positions for each swallow analyzed, however, a Bonferroni correction was applied to achieve an a level target of 0.001. For pressure peaks, duration, and contraction onset measures, multivariate analyses of variance (MANOVA) were used to determine main and interaction effects. Residual pressure and relaxation recorded in the UES (Channel 7) were analyzed in a separate repeated-measures (RM) analysis of variance (ANOVA). Peak pressures were measured from two manometric sensors in two locations during the procedure: valleculae and pyriform sinuses. Data were averaged across all three swallows for each participant and each condition for the final analysis.

Results

Head Rotation

All data for head rotation are provided in Table 1 (head rotation right) and Table 2 (head rotation left).

Pharyngeal Peak Pressures, Contraction Onset, and Duration

Multivariate ANOVA revealed no significant main effect of head rotation on pharyngeal peak pressures for the valleculae (Channel 5) or pyriform sinuses (Channel 6) ($F_6 = 0.617$, $p = 0.716$ at $a = 0.001$, $g^2 = 0.064$ and $F_6 = 1.434$, $p = 0.219$ at $a = 0.001$, $g^2 = 0.137$, respectively) or contraction onset ($F_{12} = 2.147$, $p = 0.019$ at $a = 0.001$, $g^2 = 0.193$). Multivariate ANOVA revealed significant main effects of head position for duration of pharyngeal contraction for Channel 6 ($F_{18} = 2.497$, $p = 0.001$ at $a = 0.001$, $g^2 = 0.193$). When breaking down the data into specific head positions, no significant main effects were observed. Contraction onset was faster with partial (-100 ms for R45° and -66 ms for L45°) and complete head rotations (-67 ms for R90° and -71 ms for L90°) at the pyriform sinus level (Channel 6), but not significantly.

UES Relaxation and Residual Pressure

Univariate ANOVA revealed significant main effects of head rotation on (1) UES relaxation ($F_6 = 3.456$,

Table 1 Data of the effects of partial and complete right head rotation on manometric measures

Channel	Measure	0°	R45°	*p*	R90°	*p*
Ch. 5	PP (mmHg)	188 ± 48	171 ± 42	0.657	160 ± 45	0.630
	C. (ms)	277 ± 22	250 ± 48	0.485	249 ± 44	0.811
	D. (ms)	570 ± 35	523 ± 29	0.063	485 ± 29	0.143
Ch. 6	PP (mmHg)	191 ± 20	203 ± 24	0.755	193 ± 26	0.522
	C. (ms)	322 ± 53	202 ± 18	0.202	255 ± 24	0.961
	D. (ms)	536 ± 69	412 ± 41	0.134	450 ± 40	0.430
Ch. 7	RP (mmHg)	7.5 ± 2	1.9 ± 1.6	0.044	1.16 ± 1	0.027
	R. (ms)	176 ± 26	206 ± 36	0.147	182 ± 18	0.091

PP peak pressure, *C.* contraction, *D.* duration, *RP* residual pressure, *R.* relaxation

Table 2 Data of the effects of partial and complete left head rotation on manometric measures

Channel	Measure	0°	L45°	*p*	L90°	*p*
Ch. 5	PP (mmHg)	188 ± 48	198 ± 32	0.515	190 ± 50	0.868
	C. (ms)	277 ± 22	277 ± 77	0.873	245 ± 59	0.261
	D. (ms)	570 ± 35	534 ± 86	0.673	498 ± 64	0.509
Ch. 6	PP (mmHg)	191 ± 20	187 ± 16	0.971	193 ± 29	0.585
	C. (ms)	322 ± 53	256 ± 36	0.651	251 ± 35	0.400
	D. (ms)	536 ± 69	481 ± 62	0.863	406 ± 45	0.278
Ch. 7	RP (mmHg)	7.5 ± 2	3.8 ± 1.3	0.697	2.5 ± 1.7	0.427
	R. (ms)	176 ± 26	173 ± 29	0.183	217 ± 38	0.048

PP peak pressure, *C.* contraction, *D.* duration, *RP* residual pressure, *R.* relaxation

$p = 0.001$ at $a = 0.001$, $g^2 = 0.277$) and (2) residual pressure ($F_6 = 4.697$, $p = 0.001$ at $a = 0.001$, $g^2 = 0.343$). Individual means for UES relaxation durations were increased with both right and left head rotation (partial and complete) but neither reached significance at $a = 0.001$. Left 90° head rotation compared with the neutral position revealed the most significant difference ($p = 0.048$). UES residual pressure was decreased with right 45° ($p = 0.044$) and right 90° head rotation ($p = 0.027$) compared with the neutral position and was increased with left head rotation position (partial and complete) ($p = 0.007$ and $p = 0.045$, respectively) compared with right 90° head rotation.

Chin Tuck

Data for complete chin tuck and partial (chin down) posture is provided in Table 3.

Pharyngeal Peak Pressures, Contraction Onset, and Duration

Multivariate ANOVA revealed no significant main effects of chin tuck on pharyngeal peak pressures in Channel 5 ($F_6 = 0.617$, $p = 0.716$ at $a = 0.001$, $g^2 = 0.064$) or Channel 6 ($F_6 = 1.434$, $p = .219$ at $a = 0.001$, $g^2 = 0.137$). Multivariate ANOVA did reveal significant main effects on contraction onset in the pyriform sinuses (Channel 6) ($F_6 = 4.635$, $p = 0.001$, at $a = 0.001$, $g^2 = 0.340$). Post hoc univariate testing revealed a significant effect of head position on contraction onset for the pyriform sinuses (Channel 6) between the neutral position and chin tuck ($p \setminus 0.001$), with a longer contraction onset duration with chin tuck. Multivariate ANOVA revealed significant main effects of head position on duration of pharyngeal contraction for Channel 6 ($F_{18} = 2.497$, $p = 0.001$ at $a = 0.001$, $g^2 = 0.193$). Individual pressure durations in the pyriform sinuses (Channel 6) increased for (1) chin tuck ($p = 0.012$) in comparison with the neutral position, (2) chin down ($p = 0.003$) and chin tuck ($p = 0.005$) in comparison with right 45° head rotation, (3) chin tuck ($p = 0.005$) in comparison with right 90° head rotation, and (4) chin tuck ($p = 0.008$) in comparison with left 90° head rotation; numbers did not reach significance at the $p = 0.001$ criterion. Pharyngeal contraction duration was increased in Channel 5 with chin tuck ($p = 0.009$) in comparison with the neutral position but not chin down.

Table 3 Data of the effects of partial and complete chin tuck on manometric measures

Channel	Measure	0°	Ch. down	*p*	Ch. tuck	*p*
Ch. 5	PP (mmHg)	188 ± 48	165 ± 28	0.360	206 ± 43	0.113
	C. (ms)	277 ± 22	262 ± 35	0.835	306 ± 35	0.140
	D. (ms)	570 ± 35	558 ± 25	0.120	615 ± 64	0.009
Ch. 6	PP (mmHg)	191 ± 20	203 ± 23	0.696	169 ± 21	0.205
	C. (ms)	322 ± 53	351 ± 37	0.268	411 ± 55	0.001
	D. (ms)	536 ± 69	550 ± 39	0.087	650 ± 62	0.012
Ch. 7	RP (mmHg)	7.5 ± 2.6	3.7 ± 1.5	0.819	5.85 ± 2	0.143
	R. (ms)	176 ± 26	171 ± 33	0.517	131 ± 20	0.152

PP peak pressure, *C* contraction, *D* duration, *RP* residual pressure, *R* relaxation

Multivariate ANOVA did reveal significant main effects on contraction onset in the pyriform sinuses (Channel 6, value in bold)

UES Relaxation and Residual Pressure

Univariate ANOVA revealed significant main effects of head position for (1) UES relaxation ($F_6 = 3.456$, $p = 0.001$ at $a = 0.001$, $g^2 = 0.277$) and (2) residual pressure ($F_6 = 4.697$, $p = 0.001$ at $a = 0.001$, $g^2 = 0.343$). Individual means for UES relaxation durations were decreased with chin down and chin tuck but neither reached significance at $a = 0.001$. UES residual pressure was decreased with chin down ($p = 0.819$) and chin tuck ($p = 0.143$) in comparison with the neutral position.

Discussion

The purpose of this study was to explore the use of partial versus complete head rotation and chin tuck in normal participants to determine differences in pharyngeal pressures and UES relaxation. Data from this study were collected to compare with ongoing research in patients with head and neck cancer. Overall, the data support the potential usefulness of partial head rotation (45°) but not partial chin tuck (i.e., chin down 30°), though data examining pressure changes in conjunction with bolus flow in patient populations will be necessary to confirm these findings.

Head Rotation

Head rotation has been reported to facilitate the opening of the UES by posturally providing external pull on the cricopharyngeus muscle, the bulk muscle of the UES [2]. Logemann et al. [1] reported that head rotation improved the opening of the UES by opening the diameter of the sphincter (from 7.7 to 11.6 mm compared to the mean value of 13.8 in the control group).

Head rotation (partial or complete) provided no clear benefit for pharyngeal pressures in the valleculae and pyriform sinuses. There were minimal and nonsignificant changes in pressures, and the durations of pharyngeal contraction actually decreased. Previous results [8] found some, though nonsignificant, increases in duration at the level of the velopharynx and tongue base. Placement of sensors and degree of head rotation each could play a role in the differences.

UES relaxation was significantly prolonged during head rotation, with an overall main effect; post hoc comparisons were not significant. While the greatest increase in UES relaxation duration was observed with left head rotation, a partial rotation to the right was the next most effective posture. UES residual pressure decreased in all ten patients during head rotation, and the group mean value decreased with both right 45° head rotation and complete head rotation. The increase was greater with the 90° head rotation in comparison with the neutral position.

Based on these data, the best reason for rotating the head is to increase the duration of UES relaxation pressure and decrease residual pressure; this is consistent with prior research [2, 8, 11]. Moreover, it appears that for some patients with limited mobility of the head, a partial head rotation may be better than no head rotation at all and should be considered during evaluation.

Chin Down/Chin Tuck

In this study, changes in pharyngeal pressures or UES relaxation from tucking the chin down appear to be minimal. Peak pressures increased slightly with a chin tuck in the valleculae and decreased slightly with a chin tuck in the pyriforms. There could be some clinical benefit from the chin tuck to increase pressures in the valleculae if lower pharyngeal pressures were sufficient, but this would certainly require more research to substantiate. Overall duration of contractions in both the valleculae and pyriform sinuses did increase ($p = 0.009$ and $p = 0.012$ respectively). Thus, any meaningful clinical benefit to pharyngeal pressures would lie in the duration of contraction rather than the peak pressure. Contraction onset was slower with chin tuck, however, meaning that it took longer to contract the pharyngeal muscles to peak pressure when tucking the chin. This could partially explain and potentially negate any benefit from prolonged contraction. Bülow et al. [3] and Castell et al. [7] reported negative effects on pharyngeal peak pressures and contraction durations during chin tuck and suggested that for patients who already have weak pharyngeal constrictor muscles, chin tuck would make their swallowing even worse. Our data do not negate those suggestions.

Overall, chin tuck and chin down reduced the duration of UES relaxation. Previous research [8] reported slight increases in the duration of UES opening with chin tuck. Duration of UES relaxation (i.e., duration of [50 % relaxation) is a different manometric measure than overall duration of UES opening, which includes the entire opening from start to finish, and this would explain the different results. Previously reported increases in duration of UES opening [8] were not significant anyway, but data would need to be derived from patient populations to determine the relative clinical utility of both measures in relation to bolus flow.

On the positive side, residual pressure also decreased with chin tuck and chin down. Decreases were actually better with the chin down than with the complete chin tuck. Nevertheless, the clinical significance may be minimal since head rotation (partial and complete) decreased UES residual pressure more.

Limitations of the Study

Manometry is a complicated procedure that can be cumbersome and uncomfortable for the patient. Most studies using esophageal manometry involve small samples of participants, as did ours. Larger samples could yield more significant results to solidify (or not) the trends we found. A wider range of boluses would likely provide more clinically applicable results and should be considered in future investigations. We did not use simultaneous VFSS so we not certain that the catheter was on the right side during all swallows, although our results support the probability of proper placement.

Finally, high-resolution manometry with a smaller catheter would be more in keeping with current technology and perhaps provide more conclusive results. At the least, the newer, smaller catheters would minimize patient discomfort and be less likely to affect results.

Conclusions

Despite limitations in methodology, which can limit generalization of findings, the results of this investigation support previous findings regarding the use of the chin tuck and head rotation for specific clinical purposes and indicate that partial head rotation changes pharyngeal pressures and may provide at least some clinically meaningful alteration in bolus flow to some patients. The chin tuck may be effective in generating longer upper pharyngeal pressures. The chin down posture decreases UES residual pressure but not as much as partial or complete head rotation.

Complete head rotation and complete chin tuck appear to provide the greatest benefit to most patients, although our data suggest that for patients with limited head mobility it may be worth the time and money to attempt partial head position strategies, particularly partial head rotation. This will have to be investigated in patient populations, preferably with simultaneous VFSS, to determine overall clinical utility.

Conflict of interest The authors have no conflict of interest to declare.

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