Dysphagia 14:67–72 (1999)

Dysphagia

Videomanometric Analysis of Supraglottic Swallow, Effortful Swallow, and Chin Tuck in Healthy Volunteers

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Abstract. Simultaneous videoradiography and solid-state manometry (videomanometry) was applied in eight healthy volunteers (four women, four men; age range 25–64 years, mean age 41 years) without swallowing problems. Three different swallowing techniques were tested; supraglottic swallow, effortful swallow, and chin tuck. Seven videoradiographic variables and six manometric variables were analyzed. The supraglottic swallowing technique did not differ significantly from that of the control swallows. The effortful swallow had a significantly ($p = 0.0001$) reduced hyoid–mandibular distance preswallow due to an elevation of the hyoid and the larynx, which caused a significantly ($p = 0.007$) reduced maximal hyoid movement and a significantly ($p = 0.009$) reduced laryngeal elevation during swallow. The chin tuck swallow had a significantly ($p = 0.001$) reduced laryngohyoid distance and also a significantly ($p = 0.004$) reduced hyoid–mandibular distance. The chin tuck swallow also displayed significantly ($p = 0.003$) weaker pharyngeal contractions. Videomanometry allows for analysis of bolus transport, movement of anatomical structures, and measurement of intraluminal pressures. These variables are important when evaluating swallowing techniques. In the present study, we made a few observations that never have been reported before. When healthy volunteers performed supraglottic swallow, they performed the technique somewhat differently. Therefore, we assume dysphagic patients would need a substantial period of training to perform a technique efficiently. Chin tuck could impair protection of the airways in dysphagic patients with weak pharyngeal constrictor muscles.

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Key words: Dysphagia — Videomanometry — Swallowing techniques — Supraglottic swallow — Effortful swallow — Chin tuck — Deglutition — Deglutition disorders.

Several different swallowing techniques have been used to facilitate swallowing in the rehabilitation of patients suffering from oropharyngeal dysphagia [1–3]. Techniques often used are supraglottic swallow, chin tuck, effortful swallow, and the Mendelsohn maneuver. A barium swallow is usually applied to analyze dysfunction and to determine the appropriate technique for every patient [4,5]. The rationale behind the different techniques is sometimes obvious, as in supraglottic swallow, where swallowing is followed by exhalation. This exhalation clears any bolus residue from the airways. However, there have been very few reports in the literature that describe the effects on bolus passage and movement of anatomical structures achieved by these techniques [6–8]. The present study applied simultaneous videoradiography and intraluminal manometry of three swallowing techniques to evaluate changes in bolus passage, intraluminal pressures, and movement of anatomical structures.

Materials and Methods

Simultaneous videoradiography and solid-state intraluminal manometry (videomanometry) was used in eight healthy volunteers (four women, four men; age range-25–64 years, mean age-41 years) without swallowing problems (Fig. 1). The manometry system was an intraluminal solid-state transducer system. The manometry catheter had a diameter of 4.6 mm, with four solid-state pressure transducers positioned 2 cm apart. The two proximal sensors were standard microtransducers (Konigsberg Instruments, Inc., Pasadena, CA) with a single recording site oriented radially to measure 120 degrees. The two distal

Fig. 1. Pharyngeal solid-state manometry with four sensors and a radiopaque tip at the end of the catheter. The examination was performed with the subject seated and with fluoroscopic control of the manometric sensors (lateral projection).

transducers (Konigsberg Instruments) were circumferential, allowing 360-degree measurements. The system was noncompliant; the volumetric compliance was 7×10^{-6} mm^3/mmHg, and the pressure rise rate was over 2000 mmHg/sec. The analogue signal was digitized by a Polygraph A/D converter (Medtronic, Synectics, Stockholm, Sweden). The computer was a commercial IBM-compatible computer, and the software was the Polygram Upper-GI Edition by Gastrosoft Inc./Medtronic (Synectics). All pressure values were expressed in millimeters of mercury (1.0 mmHg = 133 N/m^2, 7.5 mmHg = 1 kPa, 50 mmHg = 68 cm H_2O). The system was calibrated at 0 mmHg and at 50 mmHg. The calibration was done at 37°C. All given values are referred to atmospheric pressure. The sampling frequency was 64 Hz. The manometry catheter was introduced through the nose and fluoroscopically positioned, with its distal transducer in the pharyngoesophageal sphincter (PES). All sensors were radiopaque and easy to identify during fluoroscopy. The two proximal transducers were positioned with the recording sites in a dorsal direction. During swallowing, the pharynx–larynx elevation moved the PES in a cranial direction. When the catheter was correctly positioned in the cranial part of the PES, a characteristic M-shaped configuration of the manometry wave appeared during swallowing (Fig. 2).

The videoradiography and pharyngeal manometry were performed simultaneously in an upright position (Fig. 1) [9]. With the manometry catheter in place, all participants were instructed to swallow

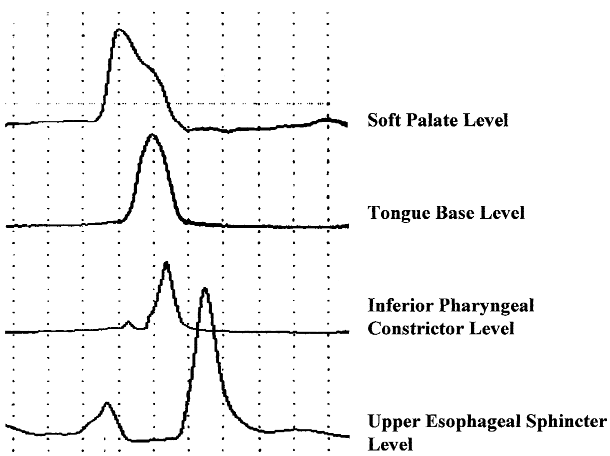

Fig. 2. Manometric tracings from the four solid-state sensors. This recording displays a normal pharyngeal peristaltic activity with normal peristaltic contractions and a complete relaxation of the upper esophageal sphincter.

10 ml of a barium contrast medium (60% weight/volume). At least three wet swallows of each technique were recorded. The videofluoroscopic image and the manometric registration were mixed using a Microeye Video Output Card (Digihurst Ltd., Roystone, UK) displayed together on a monitor and recorded together on videotape (S-VHS). Video analysis was performed by slow-motion and frame-by-frame analysis. All distances are given in millimeters and were measured on the videoframe and corrected for magnification by means of the known intersensor distance on the manometric catheter. Timing was done by calculating frame by frame with a known video speed of 1/25 sec per frame. All measures of movement of anatomical structures were done after the patient had followed the instructions applicable to each technique, e.g., after breath-hold immediately prior to swallowing with the supraglottic technique. Seven videoradiographic variables were analyzed: (a) bolus transit time, defined as the time in seconds from when the head of the bolus passed the level of the faucial isthmus until the peristaltic wave left the PES; (b) maximal hyoid movement, defined as the maximal cranioventral excursion of the hyoid bone measured from the starting position immediately prior to swallowing to the point of maximal cranioventral excursion during swallowing, (c) maximal laryngeal elevation, defined as the maximal cranial excursion of the larynx from the starting position to peak elevation, usually with the rima glottis or adjacent visible cartilage as the measuring point; (d) maximal laryngohyoid distance, defined as the maximal distance between the rima glottis or adjacent visible laryngeal cartilage and the lower margin of the hyoid bone at the starting position; (e) minimal laryngohyoid distance, defined as the shortest distance between the rima glottis or adjacent visible laryngeal cartilage and the lower margin of the hyoid bone during swallowing; (f) PES opening, defined as the maximal anteroposterior diameter of the PES during barium bolus passage; and (g) hyoid–mandibular distance, defined as the distance between the upper margin of the hyoid bone and lower margin of the mandible at the starting point immediately prior to swallowing. Six manometric variables were analyzed: (a) pharyngeal contraction pressure, defined as the maximal peristaltic peak contraction (mmHg) at the level of the inferior pharyngeal constrictor; (b) pharyngeal contraction duration, defined as the duration (msec) of the peristaltic contraction at the level of the inferior pharyngeal constrictor; (c) PES relaxation, defined as the lowest pressure (mmHg) during PES relaxation; (d) PES relaxation duration, defined as the

duration (msec) of the PES relaxation; (e) PES contraction, defined as the maximal pressure during the peristaltic contraction in the PES; and (f) coordination of PES–inferior pharyngeal constrictor, defined as time (msec) between the onset of the peristaltic contraction at the inferior constrictor level and the onset of the PES relaxation, usually a negative value, indicating that PES relaxation precedes pharyngeal contraction.

Instructions for the different swallowing techniques were given as follows. Every volunteer was given individual instruction for at least 10 min half an hour before the procedure. The procedure started with three normal wet swallows followed by the three swallowing techniques, each also performed three times, all with 10 ml thin barium liquid. When performing the supraglottic swallow, the individuals were told to take the barium liquid in the mouth, take a deep breath, hold the breath after inhalation, and then swallow while keeping the breath. Immediately after swallowing, they were instructed to cough or clear the throat before breathing again. In the effortful swallow, the individuals were instructed to swallow very hard while squeezing the tongue in an upward–backward motion toward the soft palate. The third technique was the so-called chin tuck swallowing. After taking the barium liquid in the mouth, the individuals were instructed to tuck the chin downward, swallow in that position, and after swallow raise the head. No volunteer had any problem in following the instructions or in performing the procedure.

Statistical analysis were done with repeated measures analysis of variance and multiple comparisons with Scheffe's exact test. The significance level was 0.05 for the multiple comparisons.

Results

The results are presented in Tables 1 and 2. The overall result of this study was that only a few variables changed significantly. We found some decreased movements of anatomical structures and some differences in intraluminal pressure. We did not find any differences regarding bolus transit time compared with the control swallow.

Supraglottic Swallow

No statistically significant differences were found when comparing supraglottic swallow with the control swallows. However, a couple of interesting observations were made. The laryngeal elevation was prolonged until the postswallow exhalation was completed according to this technique, which resulted in a somewhat prolonged PES relaxation (738 ± 42.2 vs. 625 ± 25.6 msec), but this difference was not significant when performing multiple comparison statistics. The videoradiographic analysis showed an increased hyoid and laryngeal elevation in six of eight volunteers after inhalation and breath-hold immediately prior to swallow. In five of eight swallows, there was also clearly visible movement of the arytenoid cartilage and a closure of the vocal folds and the Morgagni sinus (laryngeal ventricles) during breathhold. One individual elevated the shoulders slightly when performing this technique.

Effortful Swallow

A conspicuous elevation of the hyoid bone was seen in all volunteers at the initiation of this technique. There was also a significantly reduced hyoid–mandibular distance preswallow and a significantly reduced hyoid elevation during these swallows due to the early hyoid elevation in the preswallow phase when performing the maneuver. There was also a slight preswallow elevation of the larynx and accordingly a significantly reduced laryngeal elevation during swallowing.

Chin Tuck

The forward flexion of the head during this maneuver reduced all measured distances in the pharynx in all volunteers, and significant shortening was found for the following variables: maximal distance of the laryngohyoid preswallow, minimal distance of the laryngohyoid during swallow, distance of the hyoid–mandible preswallow. There were also significantly reduced pharyngeal peak contraction pressure and pharyngeal contraction duration.

Discussion

When treating patients with oropharyngeal dysfunction, the therapist, often a speech language pathologist, has to use a combination of different techniques to facilitate swallowing [2,10]. An ideal approach when planning assessment and treatment is working in a team [11]. In our clinic we have an assessment team where the radiologist and the speech language pathologist work together. At our hospital the vast majority of patients who undergo such rehabilitation are stroke patients [12]. To reestablish peroral nutrition is of immense importance for the quality of life but is also of economical and care-giving interest. The different swallowing techniques have been adopted rapidly during the last decade and are used almost worldwide. However, very few scientific publications have dealt with the mechanisms of how each technique affects swallowing [6–8].

To build a scientific basis for a better understanding of how different swallowing techniques affect swallowing in both healthy and dysphagic individuals is of great importance for the management of swallowing rehabilitation. For this purpose, videomanometry offers a combined qualitative assessment of bolus transport achieved by videoradiography with the quantitative mapping of intraluminal pressure obtained by solid-state manometry [5,9,13–18].

We have analyzed three different swallowing techniques, supraglottic swallow, effortful swallow, and chin tuck, and all of them are commonly used among

Table 1. Comparison of different swallowing techniques

	Control	Supraglottic	Effortful	Chin tuck
Bolus transit time (sec)	0.73 ± 0.02	0.74 ± 0.02	0.75 ± 0.02	0.73 ± 0.02
Maximal hyoid movement (mm)	16.3 ± 0.94	15.6 ± 1.0	12.6 ± 1.3	14.0 ± 1.4
Maximal laryngeal elevation (mm)	25.6 ± 0.78	22.6 ± 1.0	19.2 ± 1.7	19.6 ± 2.1
Maximal distance of laryngohyoid preswallow (mm)	33.2 ± 1.7	31.8 ± 1.6	31.6 ± 1.8	22.8 ± 1.9
Minimal distance of laryngohyoid during swallow (mm)	22.0 ± 1.3	21.2 ± 1.6	21.2 ± 1.4	17.3 ± 1.3
PES opening sagittal diameter (mm)	9.0 ± 0.48	9.0 ± 0.54	8.4 ± 0.4	8.4 ± 0.5
Distance of hyoid–mandible preswallow (mm)	12.9 ± 1.5	12.1 ± 1.6	5.8 ± 1.2	5.8 ± 1.6
Pharyngeal peak contraction (mmHg)	255 ± 23.6	237 ± 20.4	251 ± 30.0	193 ± 16.1
Pharyngeal contraction duration (msec)	487 ± 21.8	457 ± 16.6	501 ± 23.5	421 ± 25.0
PES relaxation (mmHg)	2.7 ± 1.9	1.1 ± 0.9	5.1 ± 2.1	0.0 ± 0.8
PES relaxation duration (msec)	625 ± 25.6	738 ± 42.2	662 ± 37.8	610 ± 29.1
PES contraction (mmHg)	278 ± 19.8	258 ± 25.3	268 ± 20.7	223 ± 20.7
Coordination of PHCI-PES (msec)	−195 ± 31.1	−215 ± 29.4	−220 ± 46.0	−232 ± 28.3

Participants included eight healthy volunteers without swallowing problems (four women, four men; age range 25–64 years, mean age 41 years). All values are means ± SEM. PES = pharyngoesophageal sphincter. PHCI = pharyngeal constrictor interior.

Table 2. Comparison of control swallows with different swallowing techniques. Statistically significant differences

Variable	Technique	*p*	95% CI
Maximal hyoid movement	Effortful swallow	0.007	1.4–6.1
Maximal laryngeal elevation	Effortful swallow	0.009	2.2–10.5
Maximal distance of the laryngohyoid preswallow	Chin tuck	0.001	7.2–12.7
Minimal distance of the laryngohyoid during swallow	Chin tuck	0.009	1.5–7.0
Distance of the hyoid–mandible preswallow	Effortful swallow	0.0001	4.9–9.3
	Chin tuck	0.004	3.1–11.0
Pharyngeal contraction	Chin tuck	0.003	30.1–95.4
Pharyngeal contraction duration	Chin tuck	0.02	14.6–117

Repeated measures one-way analysis of variance was used to compare the means of three or more matched groups. Multiple comparisons test with Scheffe's exact test determined exactly which ''treatment'' means were significantly different ($p < 0.05$). CI = confidence interval.

swallowing clinicians [1,3,19]. Our experience is that these techniques are easy for a dysphagic patient to learn, and we assumed that these techniques would be easy to learn and perform in a group of healthy individuals. Supraglottic swallow is a technique used when there is a suspicion of delayed pharyngeal swallow and an impaired vocal fold closure [2,3]. Effortful swallow can improve weakness of the tongue base. When the posterior movements of the tongue are reduced, the effortful swallow increases the movements and the pharyngeal pressures [2,3]. Chin tuck, or chin down, is one among different postural techniques, where the patient by positioning the head can facilitate swallowing. Logemann stated that this type of strategy is often the ''first line of management for oropharyngeal dysphagia. They can effectively eliminate aspiration over 50% of the time'' [2]. The chin tuck position improves airway protection [8]. When performing chin tuck, the tongue is drawn forward and the vallecular space is widened [1].

In the present study, the three techniques tested and analyzed had few significant measurable effects on the pharyngeal swallow. The volunteers performed the supraglottic swallow differently. The elevation of the hyoid bone was different. Therefore, we assume that this technique demands a period of training to perform it in an effective way or that this technique works differently depending on how different individuals perform it. Changes basically occurred in preswallow variables after the initiation of each technique. In this technique, there were no significant differences compared with the control swallows, but there was a tendency to longer duration of the relaxation of the PES. When performing this technique, the larynx starts to elevate when the individual inhales in the beginning of the technique, and the prolonged laryngeal elevation causes prolonged relaxation of the PES. Prolonged relaxation of the PES may participate in clearing the larynx more efficiently. This observation has not been reported previously. Logemann and others described the performance of the technique and the outcome when using it in different patient groups [1,2,4,8]. Martin reported that it is important to give the patient instructions to clear the throat ''out'' rather than to cough because many patients inhale before a coughing maneuver [3]. She also stated that: ''A breath-hold with fixation of the chest does not ensure glottic closure in normal patients and is probably less likely in patients with significant muscle weakness and poor endurance.'' This statement is supported by the results of the present study, with no significant changes between control swallows and supraglottic swallow but with a prolonged PES opening, as described above, that was not statistically significant. In effortful swallow, some significant differences were found. There were decreased movements of the hyoid bone and decreased laryngeal elevation, probably due to the increased muscle tension achieved when performing this technique. The tension of the muscles shortens the individual muscle of the tongue base, and the hyoid bone is then lifted. The early elevation of the larynx and the hyoid bone, well before the apex of the bolus reaches into the pharynx, may contribute to an effective protection of the larynx from the bolus by shortening the route necessary for laryngeal elevation. In patients with weak muscles in the tongue base, it may be more effective to teach the patient tongue-base retraction exercises and then the effortful swallow.

In chin tuck, we also found some significant differences and a decreased pharyngeal contraction pressure. We saw decreased distances between the larynx and the hyoid bone and also between the hyoid bone and the mandible. The decreased distances in this technique depend on the flexion of the neck, which shortens the distances in the pharynx, thereby loosening the pharyngeal constrictor muscles and, accordingly, causing less resistance in the adjacent tissues. These decreased movements of anatomical structures may be the reason for the effectiveness of the technique by shortening the route necessary for laryngeal elevation in the closure of the airways. A reduction of pharyngeal peak contraction during chin tuck pressure was also found by Castell et al. [20]. This could be a very important finding for swallowing therapy. In patients who already have weak pharyngeal constrictor muscles, a chin tuck maneuver could make the difficulties worse, especially when swallowing a thick bolus, which could lead to increased retention and even postswallow aspiration. But from our experiences from numerous barium swallow examinations, we have also learned that a chin tuck may help the patient to swallow thin liquid because this posture causes a more effective epiglottic closure and therefore prevents penetration. Therefore, it is of great importance to analyze each patient's specific dysfunction before deciding which therapeutic strategy is most efficient. The fact that we found only a few variables that changed in this series of healthy volunteers could indicate or be explained by a fixed pattern for the control of the swallowing act. However, clinical experience has taught us that these maneuvers do work in dysphagic patients. From this study, we could see that healthy volunteers perform the different techniques somewhat differently. Therefore, we assume that the period of training is extremely important before expecting the techniques to work. In chin tuck, the technique could worsen the problems if the patient has weak pharyngeal constrictor muscles, which could cause great risk for postswallow retention and aspiration. With thin liquid, the technique could still be a way to protect the airways from aspiration. This is very important information for the swallowing therapist and could provide better understanding of the whole swallowing mechanism and thus provide the patient with a more efficient and customized swallowing rehabilitation. Further studies of the swallowing techniques in patients with impaired swallowing and comparison with the present results would improve efforts to provide each patient with the opportunity to undergo successful swallowing rehabilitation.

Acknowledgment. We thank Mrs. Ewa-Rita Castoriano for computer graphics.

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