UES Opening Muscle Dysfunction

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Caryn Easterling and Reza Shaker

Abstract

The upper esophageal sphincter (UES) is composed of the cricopharyngeus (CP), the inferior pharyngeal constrictor (IPC), and the most proximal segment of the esophagus and maintains a high pressure zone between pharynx and esophagus. UES opening mechanism during deglutition is multifactorial and includes the combination of neural relaxation of tonically contracted crycopharyngeus muscle, traction forces imparted by the suprahyoid (SH) UES opening muscles, intrabolus pressure generated by the oncoming bolus, and distensibility of the UES musculature [1, 2]. Each of the aforementioned factors involved in UES opening can potentially be modified to compensate for deficiency of others in a compensated state allowing complete pharyngeal clearance; failing to do so results in an uncompensated state, diminished deglutitive UES opening resulting in incomplete pharyngeal clearance, and postdeglutitive residue and potentially postdeglutitive aspiration.

While the end result of this complex mechanism namely UES opening in health and disease has been extensively studied, the relative contribution of each of the components of this mechanism has received less and variable attention. Abnormal UES opening can be classified as *primary*, namely those due to (1) lack of neural relaxation and (2) abnormal UES distensibility, or it can be *secondary* namely due to inadequate traction forces imparted on the sphincter by the contraction of SH muscles. This chapter focuses on the latter topic.

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Anatomy and Physiology of UES Opening Muscles

Contribution of the hyoid superior and anterior movement to the opening of UES has been long recognized [1–3]. Significance of this recognition is in the implied role of the SH muscles in the opening of the UES. These UES opening muscles include those located superior and inferior to the hyoid bone. The superior hyoid group includes the geniohyoideus, mylohyoideus, stylohyoideus, hyogolossus, and anterior belly of the digastricus. As indicated by their name, the superior or SH muscles originate in locations superior to the hyoid bone and insert to its superior aspect [4]. As these muscles contract, the hyoid bone moves superiorly and anteriorly [1–3]. The anterior digastric and geniohyoid muscles are innervated by cranial nerves V and XII, while the posterior digastric and stylohyoid muscles are innervated by cranial nerve VII. The muscles inferior to the hyoid include the thyrohyoideus, sternohyoideus, sternothyroideus, and omohyoideus. The thyrohyoideus originates at the thyroid cartilage, the strenohyoideus originates from the clavicle and manubrium, the sternothyroideus originates from the manubrium and upper vertebrae, and the omohyoideus from the scapula. All of these muscles insert at the inferior portion of the hyoid bone [4]. As the inferior muscles contract they pull the hyoid bone and thyroid cartilage inferior and anterior. The action of these muscles located anterior to the UES is primarily to move the hyoid bone. The thyrohyoideus muscle forms the connection between the hyoid and larynx. As the anterior muscles simultaneously contract, the result is movement or excursion of the hyoid bone and larynx in the anterior plane.

Another muscle contributing to deglutitive UES opening is the thyrohyoid muscle. By contracting during swallowing, it locks the thyroid and hyoid together allowing transfer of force induced by contraction of SH muscles to the cricoid cartilage and CP muscle [5]. Studies have shown that thyrohyoid shortening can be augmented by strengthening the thyrohyoid muscles using rehabilitative exercises such as the Shaker Exercise [6].

The relative contribution of these muscles to UES opening during deglutition varies and has not been systematically studied. However it has been shown that SH muscle contraction is modified by oropharyngeal sensory signals induced by the volume of the swallowed bolus. This modification is evidenced by direct relationship of the extent of hyoid excursion with the volume of swallowed bolus [2, 3].

The SH and infrahyoid (IH) muscles are recruited differently during various functions involving the UES [7]. For example, concurrent videofluoroscopic and manometric studies have shown that the hyoid bone exhibits a characteristic movement pattern during belching that is different from its movement during swallowing [8]. The hyoid bone moves clockwise on an anteriorly oriented elongated loop during belching. The longer axis of the loop ranges between 0.3 and 0.8 cm, and its short axis ranges between 0.05 and 0.1 cm. The excursion loop oriented only anteriorly in the majority of study subjects (Fig. 38.1a). The duration of hyoid bone movement during a belch averaged 1.2 ± 0.12 s [3]. The movement duration was significantly shorter than the duration of hyoid bone movement ($2.1 + 0.08$ s) during swallowing ($P < 0.01$). The distinctly different excursion pattern of the hyoid bone suggests that muscles from both the SH and IH muscle groups are involved in the belch reflex, and the direction of the hyoid bone movement is

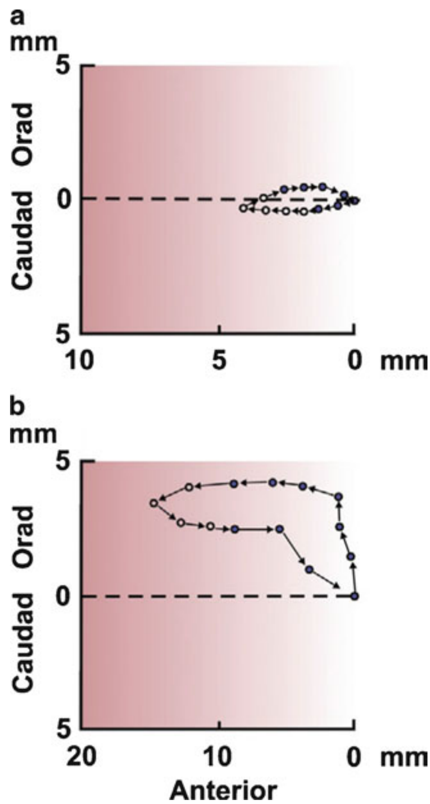

Fig. 38.1 Direction and orbit of hyoid bone movement during belching (**a**) and swallowing (**b**). *Open circles* indicate UES opening observed by videofluoroscopy (note difference in scales). Although hyoid bone movement during swallowing was invariably upward-forward and counterclockwise, its movement during belching was mainly anterior and clockwise. Magnitude of hyoid bone movement during belching was significantly less than its movement during swallowing ($P<0.01$). From Shaker et al. Am J Physiol 1992;262:G621–8 with permission

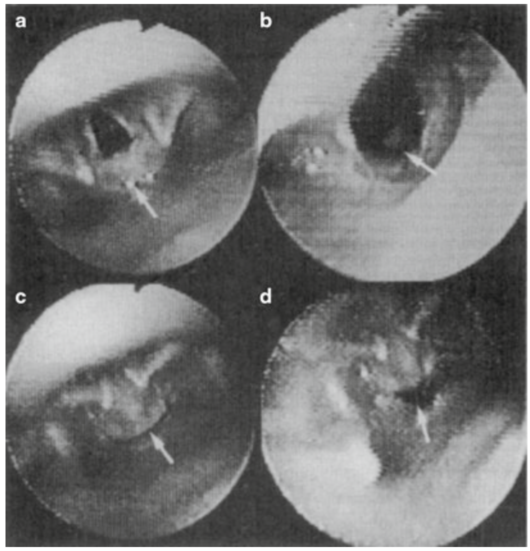

Fig. 38.2 Comparison of UES opening during belching and swallowing. (**a**) Endoscopic view of glottis and hypopharynx at rest. Area of UES opening is shown by arrow; (**b**) oval/round UES opening during swallowing; (**c**) slit-like UES opening during belching; (**d**) triangular UES opening during belching. Although shape of UES opening during belching could vary between slit-like and triangular, its shape during swallowing was oval/round. From Shaker et al. Am J Physiol 1992;262:G621–8 with permission

determined by the final vector of force that results from the summation of the opposing forces of these contracting muscle groups during belching. In contrast, the hyoid bone movement pattern during swallowing is directed superiorly and anteriorly and follows an alpha-shaped, counterclockwise loop (Fig. 38.1b). Anterior excursion of hyoid bone during swallowing averaged 1.8 ± 0.9 cm and was significantly more than its excursion of 0.78 ± 0.1 cm during belching [8].

These findings indicate the pivotal role of the SH and IH muscles in UES opening other than during swallowing. They also indicate a modification of the contraction duration, magnitude, and involvement for different members of a given muscle group depending on the specific function and related sensory input (Fig. 38.2). The sum force vector of SH and IH muscle contractions influences the shape, duration, and magnitude of UES opening. As seen in Fig. 38.1, UES opening occurs at the apogee of hyoid excursion. There is also a direct relationship between the magnitude of anterior excursion of the hyolaryngeal complex and UES opening [2, 3].

The stylopharyngeus, palatopharyngeus, pterygopharyngeus, and other superiorly and posteriorly located pharyngeal muscles make up the posterior UES opening muscles. The actions of these posterior muscles are to elevate and stabilize the posterior wall of the pharynx [4].

UES Relaxation Versus Opening

As stated earlier, successful deglutitive UES opening that results in efficient bolus transport from the pharynx through the UES and into the

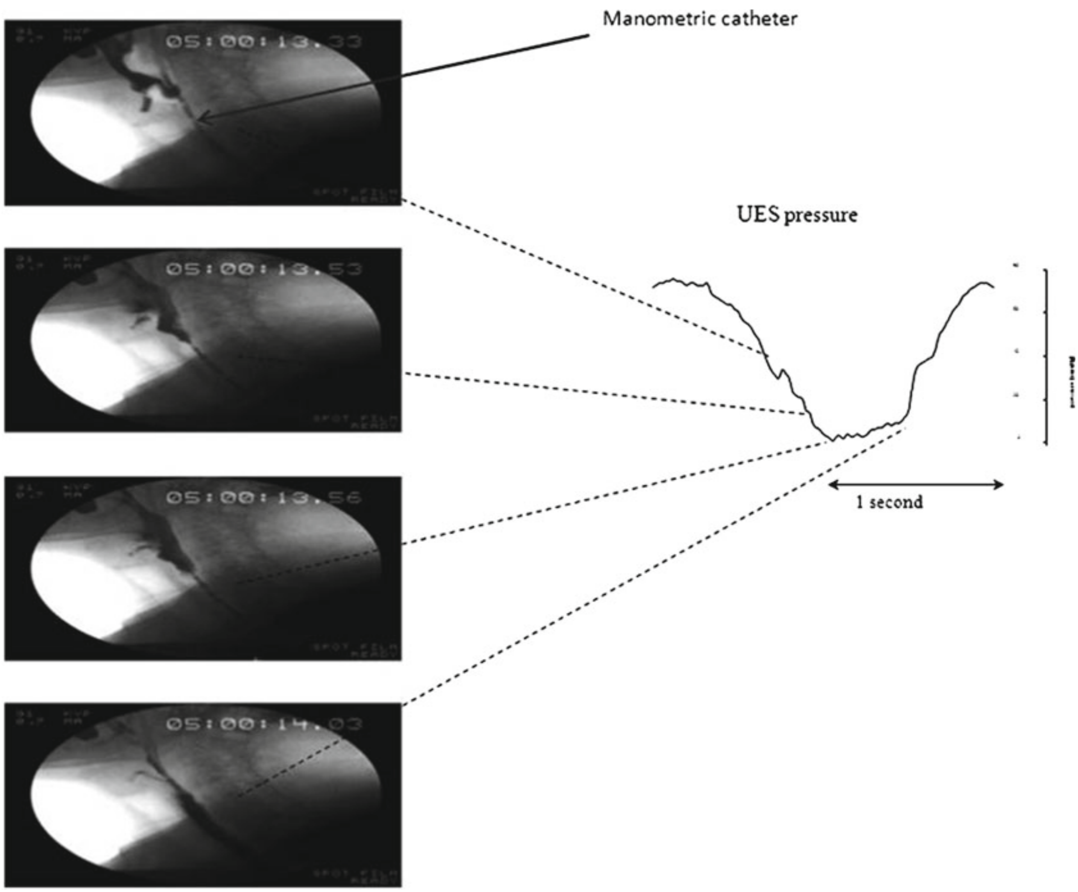

Fig. 38.3 Concurrent manometric and videofluoroscopic recording during a 5 mL barium swallow manometric relaxation is seen as a precipitous drop in pressure demonstrated in the manometric recording on the *right*. Still frames from concurrent fluoroscopic recording are shown on the *left*. Manometric recording catheter with recording sites at 1.5 cm intervals is visible in the pharynx, across the UES, and esophagus. As seen the drop in UES pressure precedes the opening of the sphincter manifested by flow of the barium bolus through the UES. While relaxation of the UES is a neural phenomenon, its opening is due to traction forces imparted on the sphincter by contraction of suprahyoid muscles

esophagus is dependent upon the following four conditions: (a) relaxation of the tonically contracted UES; (b) distraction of the sphincter as a result of the external traction forces generated by supra-hyoid muscles. This external traction results in anterior hyolaryngeal excursion and by virtue of anatomical attachment induces UES opening in anteroposterior plane during swallowing; (c) the distensibility namely the muscle property that allows the UES to stretch and accommodate the bolus passage; and (d) the distending effect of oncoming bolus and its intrabolus pressure.

During swallowing, relaxation of the UES takes place prior to the clinician's visual recognition or the radiographic documentation of the deglutitive opening of the sphincter (Fig. 38.3). Sphincter relaxation occurs during superior laryngeal excursion and occurs before opening by an average of 0.1 s. A precipitous drop in UES tone can be appreciated as a decrease in manometrically measured luminal pressure prior to the arrival of the bolus at the sphincteric segment [2, 5, 9].

Finally, intrabolus pressure namely the pressure within the fluid bolus also contributes to the UES opening. Intrabolus pressure can be measured by a manometric catheter as the bolus covers the pressure sensor. As the bolus traverses the UES, intrabolus pressure is a measure of the force required to push the fluid bolus through the open sphincter and reflects the resistance to trans-sphincteric flow [2, 5, 9].

Diminished UES Deglutitive Opening Diameter in Healthy Elderly Adults: Weakened SH Muscles or UES Traction Forces

Until recently, diminished hyolaryngeal excursion associated with decreased UES opening was mostly considered a consequence of neurologic abnormalities. Combination of advancing age and decreased physical activity can result in weakening of striated muscles. Exercise, specifically, isometric and isokinetic exercise have been shown to reverse sarcopenic changes in striated muscles of the limbs in the elderly. With regular exercise, physiologic change occurs including muscle hypertrophy, an increase in myofibrils and myosin concentration as well as changes in capillary density and an increase in connective tissue. The benefit of strengthening exercise is appreciated as cellular changes, which are then reflected in functional increase in muscular power and strength. Exercising the muscles of swallowing, specifically the SH muscles, is reasonable as they are striated muscles and will benefit from strengthening exercise. Improved strengthening of this muscle group will result in improved traction force and thus improved deglutitive function. This is the basis for the Shaker Exercise.

Alterations in the deglutitive UES opening can occur as an effect of aging [10]. If alterations or changes occur in deglutitive UES opening mechanisms, deglutitive failure or disorders may occur. The traction force although an important opening mechanism, the other three elements described above are primary to the intrinsic qualities of the muscles that make up the sphincter. The traction or distraction forces are important opening mechanisms but are described as secondary because they are extra-sphincteric, that is beyond the direct muscular or neural properties of the sphincter yet as important to the success or failure of the UES in deglutitive function.

Shaw and colleagues found that deglutitive UES compliance diminished with healthy aging resulting in increased intrabolus pressure and resistance to flow through the sphincter [11]. Disruption or weakening of the SH muscles or traction forces was thought to be the contributing cause of significantly decreased anteroposterior deglutitive UES opening diameter in healthy older adults compared to young adults [7, 10]. In a placebo-controlled study the effect of performance of a head lift exercise, also known as the Shaker Exercise, for 6 weeks was found to increase anterior deglutitive hyoid and laryngeal excursion, resulting in significantly increased anteroposterior deglutitive UES opening diameter in healthy older adults compared to young adults [7].

It was hypothesized that the Shaker Exercise could be rehabilitative in those dysphagic patients with secondary UES failure from weakened SH muscles contributing to diminished traction forces as identified through videofluoroscopic evaluation and characterized by diminished anteroposterior deglutitive UES opening diameter, postdeglutitive residuals, and postdeglutitive aspiration. The initial study found improved anterior hyolaryngeal excursion, decreased incidence of aspiration, and increased anteroposterior UES opening diameter after completion of 6 weeks of Shaker Exercise in a small group of patients with abnormal UES opening, postdeglutitive aspiration, and dependent on nonoral nutritional support [12]. Thus strengthening of the SH muscles was thought to diminish the incidence of postdeglutitive aspiration and postdeglutitive residual and improve anteroposterior deglutitive UES opening diameter.

Although the effectiveness of the Shaker Exercise in increasing UES opening during swallowing was demonstrated through manometric and videofluoroscopic studies in healthy elderly and a group of dysphagic patients, the muscle group strengthened by the exercise had not been confirmed. The preliminary studies, utilizing surface electromyography (sEMG) to evaluate the specific muscles strengthened by exercise, used spectral analysis to measure muscle fatigue of the

UES opening muscles [13–15]. A study by Ferdjallah and colleagues evaluated and quantified the sEMG activities from the SH, IH, and sternocleidomastoid (SCM) muscle groups in healthy adult controls during the isometric portion of the Shaker Exercise. The results of the spectral analysis showed that all three muscle groups showed fatigue from the 60 s isometric portion of the exercise indicating muscle strengthening. The SCM showed a higher rate of fatigue than the SH or IH muscle groups, indicating that the SCM may limit exercise as the appreciation of fatigue in the SCM prior to elicitation of fatigue and thus strengthening in the target SH group [16].

Diminished UES Deglutitive Opening Diameter in Dysphagic Patients: Weakened SH Muscles or UES Traction Forces

Volitional augmentation of UES opening has been described using the Mendelsohn Manuever, a maneuver requiring purposeful prolongation of the superior and anterior displacement of the larynx at midswallow. This purposeful prolongation results in increased duration of the anterior–superior hyolaryngeal excursion and thus maintenance of the applied traction forces. The prolongation of traction force to UES function allows for prolonged duration and extent of UES deglutitive opening [17]. The SH muscle strengthening effect of this exercise or maneuver has not been systematically studied or verified.

The Shaker Exercise, a 6-week isometric and isokinetic regimen, has been shown to strengthen the SH and the thyrohyoid muscles resulting in a significant increase in deglutitive anterior laryngeal excursion and anteroposterior deglutitive UES opening diameter in healthy older adults while decreasing the incidence of postdeglutitive aspiration and pharyngeal residual in patients with secondary UES failure due to decreased traction force. The patients included in the studies were able to discontinue feeding tube use after completion of the strengthening exercise [18].

Currently the Shaker Exercise and other rehabilitative exercises are used clinically to rehabilitate the secondary causes of abnormal UES opening, that is, dysfunction of SH UES opening muscles.

References

1. Kahrilas PJ, Dodds WJ, Dent J, Logemann JA, Shaker R. Upper esophageal sphincter function during deglutition. Gastroenterology. 1988;95(1):52–62.
2. Cook IJ, Dodds WJ, Dantas RO, Massey B, Kern M, Lang IM, Brasseur J, Hogan WJ. Opening mechanisms of the upper esophageal sphincter. Am J Physiol. 1989;257:G748–59.
3. Dodds WJ, Man KM, Cook IJ, Kahrilas PJ, Stewart ET, Kern MK. Influence of bolus volume on swallow-induced hyoid movement in normal subjects. Am J Roentgenol. 1988;150:1307–9.
4. Gray H, Goss CM. Anatomy of the human body. Philadelphia: Lea & Febiger; 1968.
5. Cook IJ, Dodds WJ, Dantas RO, Kern MK, Massey BT, Shaker R, et al. Timing of videofluoroscopic, manometric events and bolus transit during the oral and pharyngeal phases of swallowing. Am J Physiol Gastrointest Liver Physiol. 2003;284(6):G933–9.
6. Mepani R, Antonik S, Massey B, Kern M, Logemann J, Pauloski B, Rademaker A, Easterling C, Shaker R. Augmentation of deglutitive thyrohyoid muscle shortening by the Shaker Exercise. Dysphagia. 2009; 24(1):26–31.
7. Shaker R, Kern M, Bardan E, Taylor A, Stewart ET, Hoffman RG, Arndorfer RC, Hofman C, Bonnevier J. Augmentation of deglutitive upper esophageal sphincter opening in the elderly by exercise. Am J Physiol. 1997;272:G1518–22.
8. Kahrilas PJ, Dodds WJ, Dent J, Wyman JB, Hogan WJ, Arndorfer RC. Upper esophageal sphincter function during belching. Gastroenterology. 1986;91:133–40.
9. McConnell FM, Cerendo D, Jackson RT, Guffin Jr TN. Timing of major events of pharyngeal swallowing. Arch Otolaryngol Head Neck Surg. 1988;114: 1413–6.
10. Kern M, Shaker R, Arndorfer R, Hofmann C. The effect of aging on the cross sectional area of upper esophageal sphincter (UES) opening during swallowing. Gastroenterology. 1994;106:A613.
11. Shaw DW, Cook IJ, Gabb M, Holloway RH, Simula ME, Panagopoulos V, Dent J. Influence of normal aging on oral-pharyngeal and upper esophageal sphincter function during swallowing. Am J Physiol. 1995;31:G389–96.
12. Easterling C, Kern M, Nitschke T, Grande B, Daniels S, Cullen GM, Massey BT, Shaker R. Effect of a novel exercise on swallow function and biomechanics in tube fed cervical dysphagia patients: a preliminary report. Dysphagia. 1999;14:119.
13. Alfonso M, Ferdjallah M, Shaker R, Wertsch JJ. Electrophysiologic validation of deglutitive UES

opening head lift exercise. Gastroenterology. 1998; 114:G2942.
14. Jurell KC, Shaker R, Mazur A, Haig AJ, Wertsch JJ. Spectral analysis to evaluate hyoid muscles involvement in neck exercise. Muscle Nerve. 1996; 19:1224.
15. Jurell KC, Shaker R, Mazur A, Haig AJ, Wertsch JJ. Effect of exercise on upper esophageal sphincter opening muscles: a spectral analysis. Gastroenterology. 1997;112:A757.
16. Ferdjallah M, Wertsch JJ, Shaker R. Spectral analysis of surface electromyography (EMG) of upper esophageal sphincter opening muscles during head lift exercise. J Rehabil Res Dev. 2000;37:335–40.
17. Kahrilas PJ, Logemann JA, Krugler C, Flanagan E. Volitional augmentation of upper esophageal sphincter opening during swallowing. Am J Physiol. 1991;260:G450–6.
18. Shaker R, Easterling C, Kern M, Nitschke T, Massey B, Daniels S, Grande B, Kazandjian M, Dikeman K. Rehabilitation of swallowing by exercise in tube-fed patients with pharyngeal dysphagia secondary to abnormal UES opening. Gastroenterology. 2002; 122:1314–21.