The Efficacy of Supraglottic Swallow as An Indirect Swallowing Exercise by Analysis of Hyoid Bone Movement

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Supraglottic swallow (SGS) is one of the swallowing maneuvers used to enhance safe bolus passage into the esophagus and to avoid aspiration into the trachea. We examined the efficacy of SGS as an indirect swallowing exercise by quantifying hyoid bone movements during SGS. Videofluorography was used to analyze SGS in 10 healthy volunteers. SGS increased the hyoid bone posterior and superior excursion, and maintained these displacements longer, suggesting the effectiveness of the SGS as an indirect swallowing exercise. Thus SGS could be used not only as air way protection but also as an indirect swallowing exercise to strengthen the muscles adhering to the hyoid bone, and to expand the range of motion of the hyoid bone.

Key words: dysphagia, hyoid bone, biomechanical analysis, supraglottic swallow, videofluorography

INTRODUCTION

Several maneuvers have been used to facilitate swallowing in the rehabilitation of patients suffering from oropharyngeal dysphagia [1, 2], including supraglottic swallow (SGS), chin tuck, effortful swallow, and the Mendelsohn maneuver. SGS, used as a direct swallowing exercise, is a breath-holding maneuver to improve safe bolus passage into the esophagus and to decrease the incidence of aspiration into the trachea [1]. When performing the SGS, patients are told to take a breath, hold the breath after inhalation, and then swallow while keeping the breath. Immediately after swallowing, they are instructed to cough or clear the throat before breathing again. The airway protection-during-swallow aspect of this maneuver is emphasized.

On the other hand, SGS is also used as an indirect swallowing exercise in dysphagic patients to re-teach the breathing pattern during swallowing [1]. Particularly for patients with decreased laryngeal closure, SGS is taught as one of the basic exercises for airway protection.

Researchers also use biomechanical analysis of the hyoid bone as a useful tool for understanding the mechanism of swallowing [3, 4]. During swallowing, the hyoid bone generally traces a path posterior upward first, then forward, and returns to the starting position [3, 5]. The posterior superior excursion of the hyoid bone controls tongue movement during bolus passage from the oral cavity to the pharynx and leads to laryngeal elevation [5, 6]. The anterior excursion of the hyoid bone and laryngeal elevation leads to upper esophageal sphincter (UES) relaxation, anterior movement of the larynx, opening of the UES [7], and tilting of the epiglottis [8].

The excursion of the hyoid bone tends to increase during SGS, despite SGS being used for airway protection [9]. We hypothesized that SGS may be useful as an indirect exercise not only for re-teaching the breathing pattern during swallow but also for changing the motion of the hyoid bone. The aim of this study was to assess the effectiveness of SGS as an indirect swallowing exercise by analyzing the motion of the hyoid bone in the absence of a bolus.

MATERIALS AND METHODS

Videofluorography was used in 10 healthy volunteers (5 women, 5 men; age range, 24–42 years, mean age, 31.7 years) without a history of swallowing problems. No subject had a prior or existing medical condition or used medication that could potentially influence oropharyngeal motor performance or sensation.

Each subject was seated in a chair in an upright position and viewed radiographically in the lateral plane throughout the study. A radiopaque marker (Japanese 1 yen coin, diameter 20 mm) was taped to the skin of the subject's chin to serve as a stationary reference marker. The lateral videofluorographic image was displayed on a monitor and recorded on digital video disc with a DVD recorder (RDR-AX75, SONY, Japan).

Each subject performed three swallows under two different conditions: a normal swallow as the control, and an SGS. The order of these six trials was randomized. In this study, we did not use liquid barium substitute as a bolus. Subjects were instructed to remain in a resting position until the swallow command, after which they swallowed just the saliva in their mouth. For SGS, subjects were instructed and trained to hold their breath before and during swallow. Immediately after swallowing, they are instructed to cough or clear the throat before breathing again.

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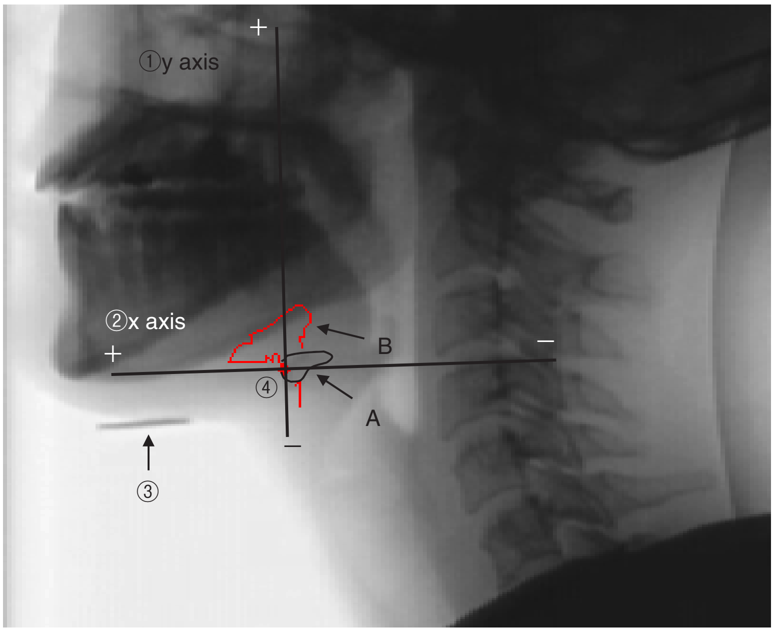

Fig. 1 A lateral view of the oral cavity and pharynx indicating the measure points

① y axis is parallel to the third cervical spinal column, ② x axis is perpendicular to the y axis, ③ reference marker (Japanese one yen coin, diameter 20 mm), ④ the dot indicates the anterior-superior corner of the hyoid bone which is the anchor point during resting and the measure point during swallow; A indicates the hyoid bone, B indicates the tracing path of the measure point.

For the spatial analysis, the following anatomic points were marked in accordance with Nakahara's method [5]: ① y axis parallel to the third cervical spinal column, ② x axis was perpendicular to y axis, ③ the reference distance (Japanese one yen coin, diameter 20mm), and ④ the anterior-superior corner of the hyoid bone. These points are illustrated in Fig. 1. The point ④ was the anchor point in the resting position and was the measure point during the swallow.

The amplitude of hyoid maximum superior excursion (MSE) was defined as the difference in its vertical position along the y axis between the resting position (anchor point) and its peak of upward motion (measure point) for each swallow. The amplitudes of hyoid maximum posterior excursion (MPE) and maximum anterior excursion (MAE) were defined similarly as the difference in horizontal position along the x axis between the resting position (anchor point) and its peak of backward or forward motion (measure points).

We marked the measure point manually frame by frame. The images were digitized at 30 frames per second and imported to an image processing system (Move Tr2D, Library Inc. Japan). The origin of the image processing system was referenced to the anchor point (point 0.0 mm). Fluoroscopic magnification was corrected using the reference distance. Thus, the reference distance allowed us to measure the absolute extent of hyoid movement.

Timing of the beginning and the end of the swallow was determined by direct reading of the digital time recorded on each video frame. The beginning of the swallow was determined as the start of the backward movement of the hyoid bone after the command to swallow, and the end was determined as the return to the resting position.

For the durational analysis, we measured the duration of superior displacement of the hyoid bone from the resting position to re-crossing of the x axis, and that of posterior displacement from the resting position to re-crossing of the y axis.

We averaged the data with or without maneuver and compared the two conditions within individuals. The paired differences between swallowing conditions were tested with Wilcoxon's rank-sum test and a p value less than .05 was considered statistically significant.

RESULTS

Spatial measure

The vertical and horizontal excursion of the hyoid bone during swallow with and without maneuver is shown in Fig. 2. MSE and MPE with SGS were significantly larger than with normal swallow (control), whereas the MAE showed no significant difference.

Durational measure

The posterior displacement time and superior displacement time of the hyoid bone were significantly longer with SGS compared with normal swallow (control) (Fig. 3).

DISCUSSION

We found a statistically significant increase in posterior and superior hyoid bone excursion, and longer displacement time, when subjects performed SGS without a bolus compared to normal swallowing. However, previous studies that analyzed hyoid bone movement with liquid barium SGS, indicated that hyoid position was not affected by the breath-holding maneuver (Table). Ohmae *et al.* [9] reported that breath-holding maneuvers raised the vertical laryngeal position before the pharyngeal swallow. But they concluded that hyoid position was not affected by the breath-holding maneuver. Significant differences were not recognized between the vertical and horizontal hyoid bone position with maneuver and that position without maneuver during swallowing of liquid barium as the bolus. There was no pharyngeal manometric change with this maneuver [10, 11]. There has been no report to date regarding biomechanical analysis of the hyoid

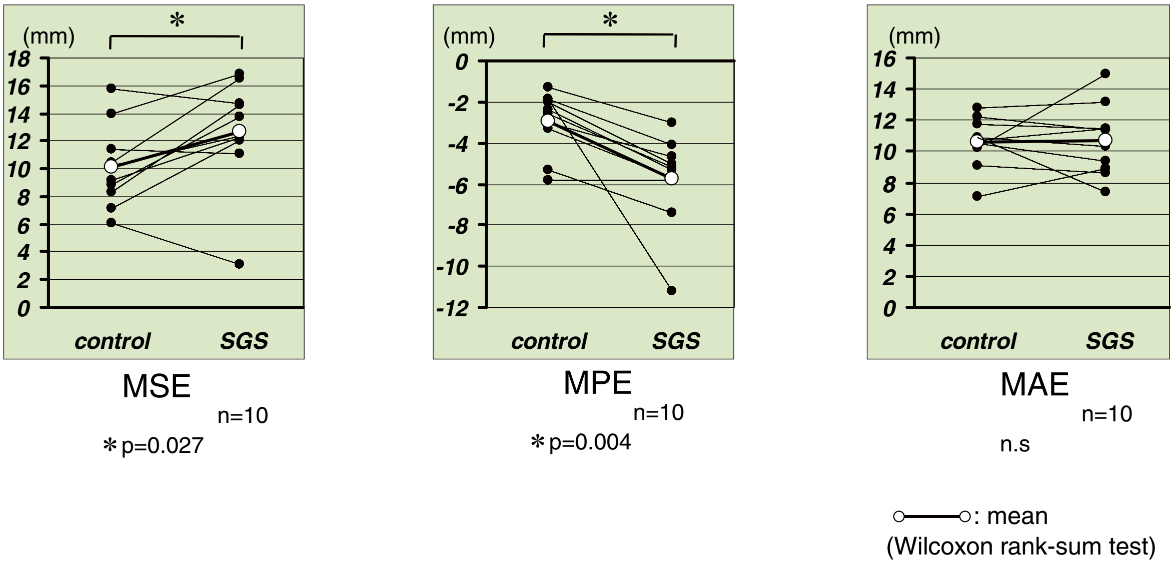

Fig. 2 Spatial analysis
MSE and MPE with SGS were significantly larger than with normal swallow (control). On the other hand, the MAE of the hyoid bone showed no significant difference with the maneuver.
Abbreviation: MSE, maximum superior excursion; MPE, maximum posterior excursion; MAE, maximum anterior excursion

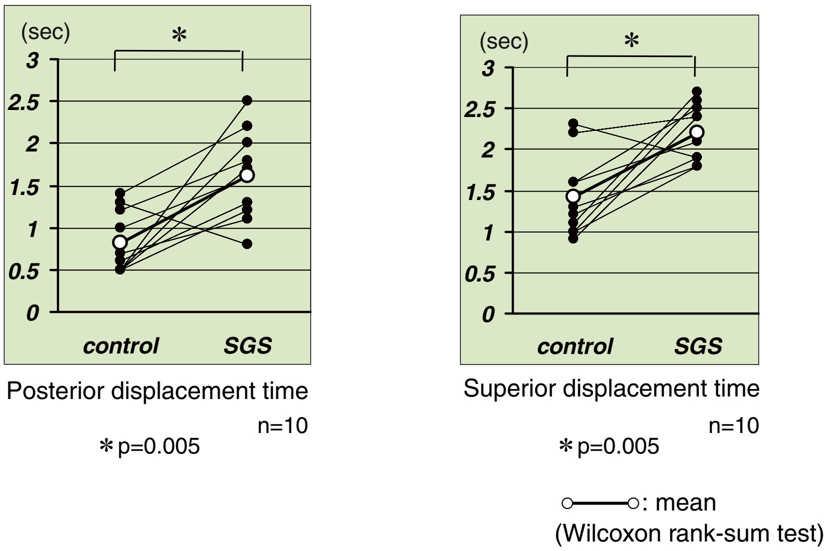

Fig. 3 Durational analysis
The posterior displacement time and superior displacement time of the hyoid bone were significantly longer with SGS compared with the control.

Table Previous reports on analysis of supraglottic swallow

Year	Author	Subjects	Bolus	Maximal superior excursion change of hyoid bone	Maximal pharyngeal manometric change	Other
1996	Ohmae Y et al 9)	8 healthy volunteers (all men, 20–28 y/o)	5 ml liquid barium	n.s	No analysis	Tendency of increasing superior excursion of hyoid bone
1999	Bülow M et al 10)	8 healthy volunteers (women 4, men 4, 25–64 y/o, mean 41 y/o)	10 ml liquid barium	n.s	n.s	Prolonged laryngeal elevation, tendency of inceasing superior excursion of hyoid bone
2002	Bülow M et al 11)	8 dysphgic patients (women 4 , men 4, 46–81 y/o, mean 70 y/o)	10 ml liquid barium	No analysis	n.s	Tendency to higher intrabolus pressure

n.s.= not significant.

bone during swallowing without a bolus.

In the present study, to assess another aspect of SGS, namely its efficacy as an indirect exercise, we did not use a liquid barium bolus. This allowed subjects to swallow easily and powerfully, without worrying about aspiration. We believe this is the reason for the significant difference in the motion of hyoid bone found this study compared with previous reports.

According to one previous report, during SGS as a direct swallowing exercise, the larynx starts to elevate when the subject inhales at the beginning of the maneuver, and prolonged laryngeal elevation causes prolonged relaxation of the UES, which may in turn participate in clearing the larynx more efficiently [10]. The main mechanism of laryngeal elevation associated with breath holding is apparently dependent on the contraction of the thyro-hyoid muscle, which is the main muscular attachment between the hyoid bone and thyroid cartilage [9]. The results from the present study indicate that SGS, as an indirect swallowing exercise, enhances the effect of airway protection compared to this maneuver as a direct swallowing exercise, although SGS has been regarded as a warm-up to re-teaching the procedure of airway protection. SGS without a bolus may be useful as an indirect swallowing exercise for strengthening the muscles adhering to the hyoid bone, and for expanding the range of motion of the hyoid bone. We have demonstrated that this maneuver improves swallowing movement in normal young subjects.

Logemann *et al.* [12] analyzed the biomechanical difference of swallow between younger and older people. They reported that the older people exhibited significantly reduced maximum vertical and anterior hyoid bone movement as compared to the younger people. These data support the hypothesis of reduced muscular reserve in the swallows of older people as compared to younger people. We think that the SGS as an indirect swallowing exercise is not only effective for even older people but also more important for those people.

SGS is a somewhat complex maneuver which is not easy to apply in the patients with dementia. Chaudhuri *et al.* [13] reported the possibility of SGS enhancing the Valsalva maneuver which causes a cardiovascular effect such as arrhythmias in stroke patients. Therefore, we need to further study practical applications of this maneuver for the patients with coronary disease or stroke.

We did not assess the training effect of SGS as an indirect swallowing exercise, in particular for dysphagic patients. Future studies will assess the training effects on hyoid bone movement, and the effects on the strength of muscle adherence to the hyoid bone, using this maneuver as an indirect swallowing exercise in dysphagic patients.

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REFERENCES

1) Logeman JA. Evaluation and treatment of swallowing disorders. San Diego: College-Hill Press, 1983.
2) Logemann JA: Dysphagia: evaluation and treatment. Folia Phoniatr Logop 1995; 47: 140-164.
3) Ekberg O. The normal movements of the hyoid bone during swallow. Invest Radiol 1986; 21: 408-410.
4) Ishida R, Palmer JB, Hiiemae KM. Hyoid motion during swallowing: factors affecting forward and upward displacement. Dysphagia 2002; 17: 262-272.
5) Nakahara M. A cinefluorographic study of hyoid and laryngeal movements during deglutition. Journal of Otolaryngology of Japan 1987; 90: 669-679.
6) Palmer JB, Rudin NJ, Lara G, Crompton AW. Coordination of mastication and swallowing. Dysphagia 1992; 7: 187-200.
7) Cook IJ, Dodds WJ, Dantos RO, Massey B, Kern MK, Lang IM, *et al.* Opening mechanisms of the human upper esophageal sphincter. Am J Physiol 1989; 257: 749-759.
8) Vandaele DJ, Perlman AL, Cassell MD. Intrinsic fibre architecture and attachments of the human epiglottis and their contributions to the mechanism of deglutition. J Anat 1995; 186: 1-15.
9) Ohmae Y, Logemann JA, Kaiser P, Hanson DG, Kahrilas PJ. Effects of two breath-holding maneuvers on oropharyngeal swallow. Ann Otol Rhinol Laryngol, 1996; 105: 123-131.
10) Bülow M, Olsson R, Ekberg O. Videomanometric analysis of supraglottic swallow, effortful swallow, and chin tuck did not alter hypopharyngeal intrabolus pressure in patients with pharyngeal dysfunction. Dysphagia 1999; 14: 67-72.
11) Bülow M, Olsson R, Ekberg O. Supraglottic swallow, effortful swallow, and chin tuck in healthy volunteers. Dysphagia 2002; 17: 197-201.
12) Logemann JA, Pauloski BR, Rademaker AW, Calangelo LA, Kahrilas PJ, Smith CH. Temporal and biomechanical characteristics of oropharyngeal swallow in younger and older men. J Speech Hear Res 2000; 43: 1264-1274.
13) Chaudhuri G, Hildner CD, Brady S, Hutchins B, Aliga N, Abadilla E. Cardiovascular effects of the supraglottic and super-supraglottic swallowing maneuvers in stroke patients with dysphagia. Dysphagia 2002; 17: 19-23.