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Influence of neck postural changes on cervical spine motion and angle during swallowing

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Abstract

Occipitocervical (OC) fixation in a neck retraction position could be dangerous due to the risk of postoperative dysphagia. No previous study has demonstrated an association between the cervical posture change and cervical spine motion/angle during swallowing. So, we aimed to analyze the influence of neck posture on the cervical spine motion and angle change during swallowing.

Thirty-seven asymptomatic volunteers were recruited for participation this study. A videoflurographic swallowing study was performed in the neutral and retracted neck posture. We analyzed the images of the oral and pharyngeal phases of swallowing and compared the angle and the position changes of each cervical segment.

In the neutral posture, C1 and C2 were flexed, while C5, C6, and C7 were extended. C3, C4, C5, C6, and C7 moved posteriorly. All cervical levels, except for C5, moved superiorly. In the retraction posture, C0 and C1 were flexed, while C6 was extended during swallowing. All cervical levels moved posteriorly. C1, C2, C3, and C4 moved superiorly. The comparison between 2 postures shows that angle change is significantly different between C0, C2, and C5. Posterior translation change is significantly different in the upper cervical spine (C0, C1, and C2) and C7. Superior movement is significantly different in C0.

C0 segment is most significantly different between neutral and retraction posture in terms of angle and position change. These data suggest that C0 segment could be a critical level of compensation that allows swallowing even in the retraction neck posture regarding motion and angle change. So, it is important not to do OC fixation in retraction posture. Also, sparing C0 segment could provide some degree of freedom for the compensatory movement and angle change to avoid dysphagia after OC fixation.

Abbreviations: OC = occipitocervical, VFS = videofluoroscopic study.

Keywords: cervical spine, compensation mechanism, dysphasia, neck posture, swallowing, videoflurographic study

1. Introduction

Dysphagia may occur following anterior or posterior cervical fusion.[1–6] Postoperative dysphagia may pose an obstacle to the activities of daily living; moreover, it is occasionally life-threatening, especially when it is combined with dyspnea. Sequelae of dysphagia, such as undernutrition, dehydration, and pneumonia, can result in prolonged hospitalization or medical treatment. Riley et al[7] showed that, following cervical spinal surgery, patients with dysphagia experienced significantly more functional disability and had poorer physical health as compared to healthy subjects.

Previous studies have examined the relationship between swallowing and the cervical spines of patients undergoing cervical fusion in several contexts, including dysphagia. Major risk factors of postoperative dysphagia after anterior cervical fusion include intraoperative retraction of the esophagus with a decrease in mucosal perfusion, multilevel procedures, and the patient's age.[8–10] Chen et al[11] reported that risk factors for dysphagia after anterior-posterior cervical surgery were increased number of exposed anterior levels, anterior surgery that extended above C4, and enhanced requirements for surgical correction of C2–7 lordosis. Matsuyama et al[12] reported that posterior total cervical fusion in a flexed position may cause dysphagia or even, in rare cases, dyspnea. It has been reported that the decrease in the occipito–C2 angle induces a reduction of the pharyngeal space and can be a predictor of postoperative dysphagia.[13–15]

Although dysphagia is a multifactorial pathology, a literature analysis of dysphagia after the cervical spine fusion suggests that a decrease in the cervical spine motion and in the angle itself can be a risk factor of dysphagia. Therefore, it is important to understand the cervical spine movements during swallowing. Mekata et al[16] reported that the cervical spine moves to reduce physiological lordosis during deglutition in the neutral position. However, no prior study has demonstrated an association between cervical posture and the change of cervical spinal motion/angle during swallowing.

A "military tuck" posture (neutral head posture, extension of the lower cervical spine, posterior translation of the occiput-C1 complex) usually reduces C1–2 subluxation while optimizing the

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surgical exposure and allowing for a favorable screw trajectory.[14,15] It is a commonly used posture together with neutral posture for posterior instrumentation in the upper cervical spine. Therefore, a thorough assessment of these 2 postures (neutral and retraction) is essential to evaluate the relationship between the swallowing and change of motion/angle of the cervical spine. The purpose of the present study was to investigate the influence of the neck's postural change on the cervical spinal motion and angle during swallowing.

2. Methods

2.1. Subjects

The study group consisted of 37 healthy volunteers (18 male and 19 female) aged from 20 to 75 years (mean ± SD, 42.7 ± 19.7 years) who were without symptoms or signs of swallowing problems, without histories of cervical spinal disease, temporomandibular joint disease, or cerebrovascular disease. Each participant filled in questionnaires about their medical history. The study protocol was approved by the Institutional Review Board of our hospital and all participants were informed of the potential experimental risks and were requested to sign a consent form.

2.2. Postures

The subjects were first instructed to drink a liquid in the "neutral" or "normal and comfortable" posture. The instruction given to the patients for the "retraction" posture was "tuck your chin as close to your neck as possible," "intentionally bring or touch your chin to your neck," or "maximal backward gliding of the head" (Fig. 1A–D). In an attempt to minimize upper thoracic motion, the patients were instructed to maintain both their upper thoracic spine and shoulders in close contact with the back of the chair throughout the tests. Each subject was instructed about the

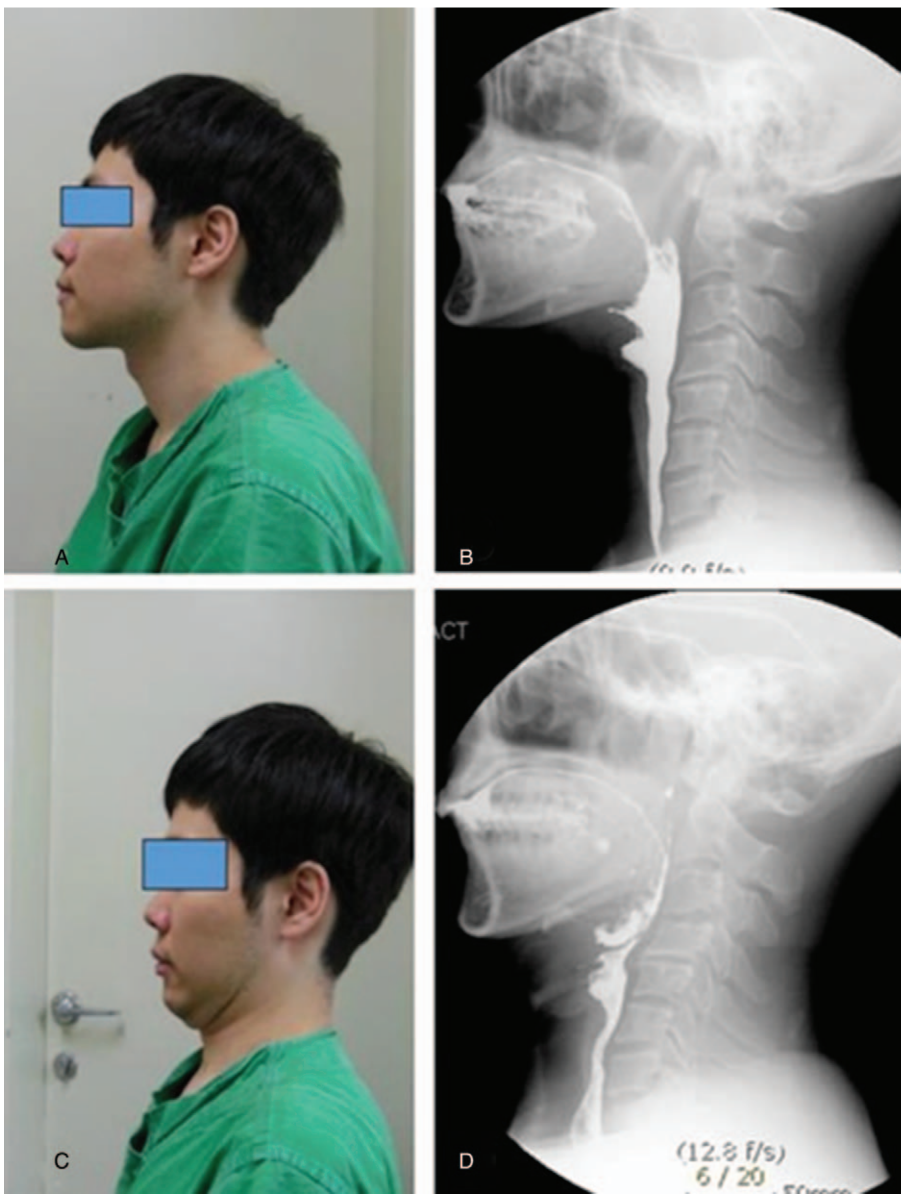

Figure 1. (A, B) Neutral posture and its videoflurographic image. (C, D) Retraction posture and its videoflurographic image. Hyperflexion of the upper cervical spine decreased the occipitocervical angle, which resulted in narrowing of the oropharyngeal space. This mechanical obstruction cause dysphagia after occipitocervical fusion.

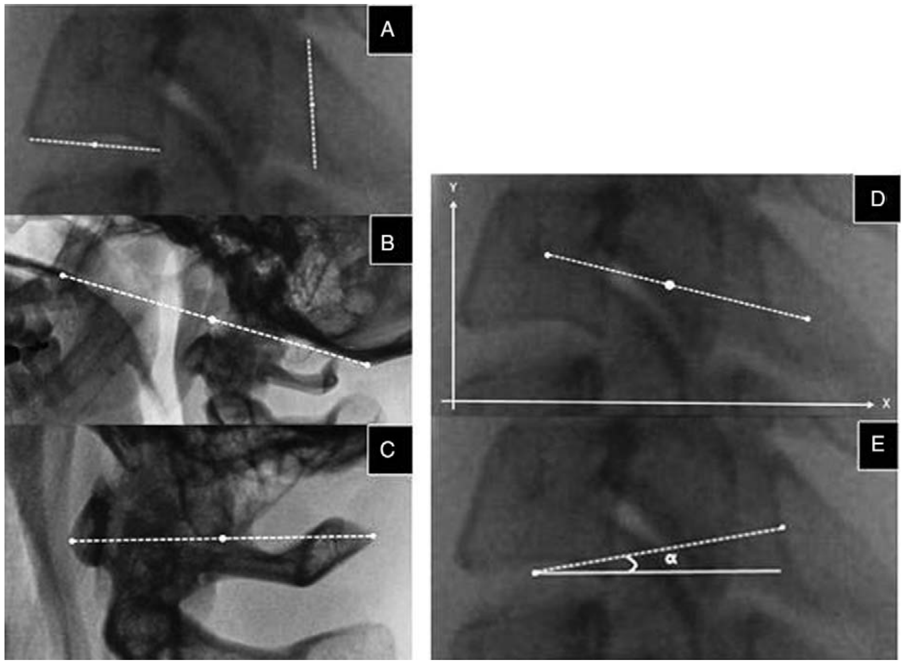

Figure 2. (A) The 2 white dots are the reference points; mid-point of inferior vertebral body line and spino-lamina junction line. (B) Target position of cervical spine. The anterior-posterior coordinate is X, and the superior-inferior coordinate is Y. The large white dot is the target position; midpoint of the line connecting the 2 reference points. (C) Angle α. The white dotted line connects the 2 reference points. The white solid line is a horizontal line. The angle α is defined by these 2 lines and indicate the angle of each cervical vertebra.

positions and was allowed to practice swallowing before imaging. All subjects expressed subjective dysphagia when they tried to swallow in the retracted posture. No subject complained of dysphagia in the neutral posture. The video fluoroscopic recording was performed in the order of each position. Only a single swallow in each position was recorded and analyzed.

2.3. Videofluoroscopic study (VFS) of swallowing

Videofluorography was conducted by referencing the Manual for the VFS of Swallowing.[17–20] The images were acquired on a mobile fluoroscopy system (Medix 3000, Hitachi, Japan); 2-dimensional (2D) digitization of the swallowing motion was performed with the same system. The subjects were seated upright in a chair for the duration of the study. Their heads were not stabilized, but their motions were monitored. Oral contrast agents, consisting of 10 mL of 35% barium sulfate diluted in water, were given to the subjects for ingestion.

2.4. Imaging analysis

The oral phase was defined as the period during which the subject takes and holds barium sulfate in the mouth. The pharyngeal phase was defined as the period during which the hyoid bone elevates to the highest possible position. The phase extraction was performed and the extracted still images were analyzed using m-view 5.4 software (Marosis Technologies, Inc., Seoul, Korea). The borders of the vertebral body and the spinous process were specified by adjusting the contrast and the brightness of an extracted still image from a section of the cervical spine. The images were magnified by 500% and then analyzed.

In the present study, the midpoint of the inferior end plate of the vertebral body and the midpoint of the spino-lamina junction line were used as reference points (Fig. 2A). In C0 (occiput), we used the posterior edge of the hard palate and the most caudal point of the occipital curve (McGregor line) as reference points. In C1, the anterior and the posterior tubercles were used as reference points. In addition, the midpoint coordinates between these 2 reference points were determined as the target position in the cervical spine. To calculate the coordinates of each point, we defined the x-axis as a horizontal line and the y-axis as a vertical line perpendicular to the x-axis (Fig. 2B). An angle between a straight line that passed through 2 reference points and a horizontal line was defined as the angle of each cervical vertebra (Fig. 2C). In the same window, we measured the difference values of the target positions and the angles between the oral and the pharyngeal phases. The difference values were determined in the pharyngeal phase with respect to the oral phase.

2.5. Evaluation of reliability

To evaluate the intra-rater reliability of this study, the x and y coordinates and the angles in both the oral and pharyngeal phases were calculated and compared. Inter-observer variability analyses were performed to ensure a close correlation between the measures obtained by the 2 observers.

2.6. Statistical analysis

SPSS Statistical software version 18.0 (SPSS, Inc., Chicago, IL) was used for statistical analyses. For the statistical analysis, the null hypothesis was formulated as follows: “The position and angle changes of each cervical vertebra would be zero.” Subsequently, a 1-sample t test was used. The paired t test was used for the comparisons between the neutral and the retraction postures of the positions and the angle changes of each cervical vertebra during swallowing. For all statistical tests, $P < .05$ was considered to be statistically significant.

Table 1

The measurements of angle change, movement X, and movement Y in neutral and retraction positions.

	Neutral position			Retraction position		
	Angle change, °	Movement X, mm	Movement Y, mm	Angle change, °	Movement X, mm	Movement Y, mm
C0	0.30±0.23†	−0.49±0.49†	0.61±0.20*,†	−0.77±0.34*,†	1.35±0.47*,†	0.03±0.20†
C1	−1.37±0.61*	−0.40±0.42†	0.59±0.12*	−0.63±0.21*	1.65±0.52*,†	0.43±0.11*
C2	−1.94±0.50*,†	0.32±0.29†	0.87±0.14*	−0.25±0.27†	1.75±0.50*,†	0.50±0.13*
C3	−0.86±0.44	0.88±0.28*	0.63±0.10*	−0.82±0.42	1.86±0.55*	0.60±0.11*
C4	0.08±0.16	1.50±0.30*	0.49±0.07*	−0.09±0.28	2.11±0.44*	0.61±0.18*
C5	0.87±0.19*,†	1.17±0.27*	0.28±0.09*	−0.35±0.32†	2.06±0.44*	0.06±0.17
C6	0.97±0.18*	0.89±0.21*	0.10±0.09	0.58±0.23*	1.43±0.42*	0.21±0.11
C7	0.75±0.33*	0.60±0.21*,†	0.20±0.07*	0.10±0.26	1.45±0.39*,†	0.19±0.11

Positive values represent extension, posterior movement, and superior movement in angle changes, movement x, and movement y.

* Significant $P<.05$ in 1-sample t test for assuming the null hypothesis, "The position and angle changes of each cervical vertebra is zero."

† Significant $P<.05$ in paired t test for comparisons of the position and angle changes of each cervical vertebra between neutral and retraction positions, Value: mean±SEM.

3. Results

Table 1 summarizes the angle changes and the movements of each cervical segment in the pharyngeal phase as compared to those in the oral phase for both postures.

3.1. Neutral posture

In the pharyngeal phase of the neutral posture, C1 and C2 were flexed by 1.37° ($P<.01$) and 1.94° ($P<.01$), while C5, C6, and C7 were extended by 0.87° ($P<.01$), 0.97° ($P<.01$), and 0.75° ($P=.03$) in reference to the oral phase, respectively. C0 and C4 were extended by 0.30° ($P=.21$) and 0.08° ($P=.63$), respectively, while C3 was flexed by 0.86° ($P=.06$). However, the results were not statistically significant. The average total lordosis angle ranging from C0 to C7 was 22.34° in the oral phase and 21.14° in the pharyngeal phase, resulting in a decrease in cervical lordosis by 1.20° (Fig. 3 A).

C3, C4, C5, C6, and C7 moved posteriorly by 0.88 mm ($P<.01$), 1.50 mm ($P<.01$), 0.17 mm ($P<.01$), 0.89 mm ($P<.01$), and 0.60 mm ($P<.01$), respectively. Although C0 and C1 moved anteriorly by 0.49 mm ($P=.32$), 0.40 mm ($P=.35$), respectively, and C2 moved posteriorly by 0.32 mm ($P=.28$), no statistically significant differences were found (Fig. 4 A).

C0, C1, C2, C3, C4, C5, and C7 moved superiorly by 0.61 mm ($P<.01$), 0.59 mm ($P<.01$), 0.87 mm ($P<.01$), 0.63 mm ($P<.01$), 0.49 mm ($P<.01$), 0.28 mm ($P<.01$), and 0.20 mm ($P<.01$), respectively. While C6 moved superiorly by 0.10 mm ($P=.29$), no statistically significant difference was observed (Fig. 4 C).

3.2. Retraction postures

In the pharyngeal phase of the retraction posture, C0 and C1 were flexed by 0.77° ($P<.05$) and 0.63° ($P<.01$) in reference to the oral phase, respectively, while C6 was extended by 0.58° ($P<.05$). C2, C3, C4, and C5 were flexed by 0.25° ($P=.35$), 0.82° ($P=.06$), 0.09° ($P=.75$), and 0.35° ($P=.27$), respectively, while C7 was extended by 0.10° ($P=.69$). However, these results were not statistically significant. The average total kyphosis angle ranging from C0 to C7 was 12.54° in the oral phase and 14.77° in the pharyngeal phase, resulting in an increase in cervical kyphosis by 2.23° (Fig. 3B).

C0, C1, C2, C3, C4, C5, C6, and C7 moved posteriorly by 1.35 mm ($P<.01$), 1.65 mm ($P<.01$), 1.75 mm ($P<.01$), 1.86 mm ($P<.01$), 2.11 mm ($P<.01$), 2.06 mm ($P<.01$), 1.43 mm ($P<.01$), and 1.45 mm ($P<.01$), respectively (Fig. 4B).

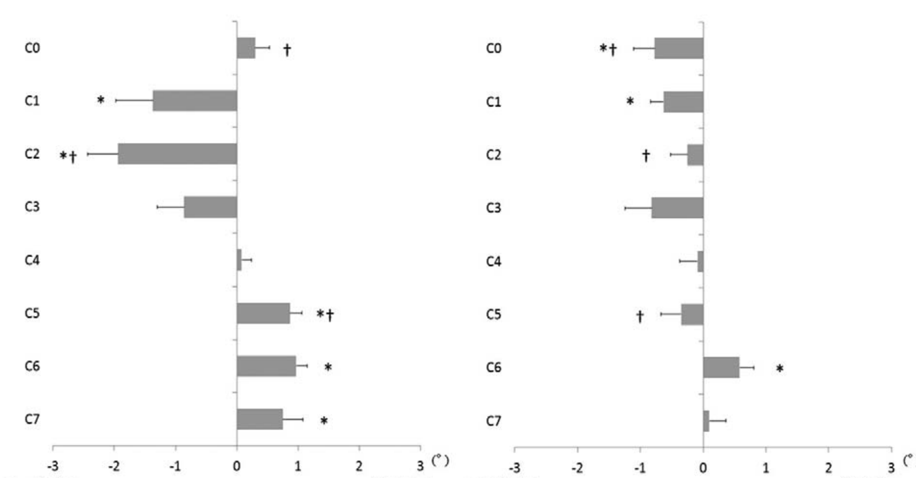

Figure 3. (A) In neutral posture, changes in the angle of the cervical spine. (B) In retraction posture, changes in the angle of the cervical spine. Bar: mean±SEM, * Significant $P<.05$ in 1-sample t test, †Significant $P<.05$ in paired t test.

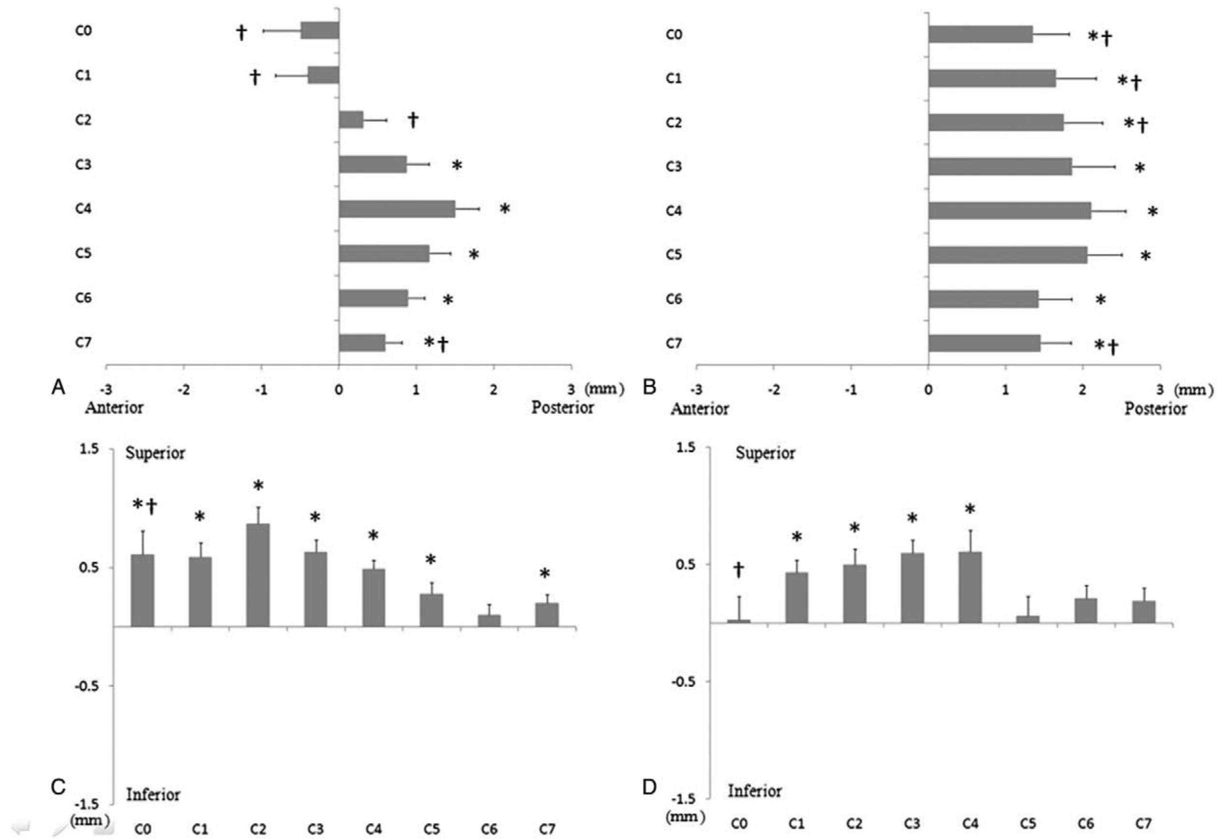

Figure 4. (A) In neutral posture, X movements (anterior-posterior direction) of the cervical spine. (B) In retraction posture, X movements (anterior-posterior direction) of the cervical spine. (C) In neutral posture, Y movements (Inferior-superior direction) of the cervical spine. (D) In retraction posture, Y movements (Inferior-superior direction) of the cervical spine. Bar: mean ± SEM, *Significant $P<.05$ in 1-sample t test, †Significant $P<.05$ in paired t test.

C1, C2, C3, and C4 moved superiorly by 0.43 mm ($P<.01$), 0.50 mm ($P<.01$), 0.60 mm ($P<.01$), and 0.61 mm ($P<.01$), respectively. While C0, C5, C6, and C7 moved superiorly by 0.03 mm ($P=.85$), 0.06 mm ($P=.70$), 0.21 mm ($P=.07$), and 0.19 mm ($P=.08$), respectively, the results were not statistically significant (Fig. 4D).

4. Discussion

There have been several studies that compare the angle and motion between preoperative and postoperative images in patients with OC fixation.[13–15,21]

Although previous studies showed that the decrease in the OC2 angle in the retraction position cause a reduction of the oropharyngeal airway space and postoperative dysphagia, there have been few studies about compensatory reaction of the cervical spine during swallowing yet.

The most unique feature of the present study is that our method allows for presenting the changes in the locations and the angles of the cervical vertebrae at each point in time during swallowing in different postures. In this way, our study has demonstrated the angular movement of each cervical segment, as well as the vertical and the horizontal movements, which have not been previously reported with regard to postural change of the neck.

In the pharyngeal phase of the neutral posture, C1 and C2 were flexed and C5-C7 were extended, which resulted in a decrease in the C0-C7 cervical lordosis angles. These results were similar to those reported by Mekata et al[16] in a study of cervical motion during swallowing. In the retraction posture, the C0-C7 angles became kyphotic as compared to those in the neutral posture, for which C0-C5 were flexed and C6-C7 were extended during swallowing. Cervical kyphosis increased more in the pharyngeal phase of the retraction position. Except for C0 segment, the tendency of the absolute values of the cervical angle changes in the retraction position during swallowing was less pronounced than that in the neutral position. The posterior movements in the retraction posture were larger than in those of the neutral posture, while the superior movements, except for that of C0, did not differ. These findings suggest that there were increases in posterior translation, kyphotic angle changes, and decreases in absolute angle changes in the retraction posture as compared to the neutral posture.

An interesting finding of the present study is that there is a significant difference of C0 and C2 segmental angular motion between the neutral and retraction positions. The flexion of C1 and C2 mainly contribute to the reduction of lordosis in the neutral position. However, the flexion of C0 and C1 become the main segment to allow angular motion in the retraction position. The largest angular motion during swallowing was detected at C2 followed by C1 in the neutral posture. However, angular motions become quite different in the retraction position. The largest angular motion was detected at C0 and the angular motion of C1 and C2 become smaller in retraction position. C0 angular change is becoming prominent in the retraction position, which might be a critical compensatory reaction for swallowing.

In our study, the global cervical spine has demonstrated a tendency to flex and reduce physiological lordosis during swallowing both in the neutral and retracted positions. Swallowing is a complex mechanism using both skeletal muscle (tongue) and smooth muscles (pharynx and esophagus). During the swallowing process, a complex and precisely coordinated succession of muscular contractions and relaxations occurs.[20,22] Strengthening exercises on swallowing musculature and function show that healthy senior subjects were able to significantly increase the swallowing muscle strength and volume.[23,24] We can speculate that the movement of these structures is associated with the cervical spinal motion and angle during swallowing. Some studies have offered explanations for this movement. Specifically, Mekata et al[16,25] reported that the muscular movements directly related to swallowing and that the relationship among the muscles directly related to deglutition cause a decrease in physiological lordosis of the cervical spine.

Dysphagia is not an uncommon postoperative complication after posterior cervical surgeries, as well as following anterior cervical spine surgeries.[7,10,21,26,27] Moreover, dysphagia after posterior occipitocervical (OC) fusion has been recognized as a serious postoperative complication.[21,28] Miyata et al[13] reported that the decrease in the occipito–C2 angle induces a reduction of the pharyngeal space and can be a predictor of postoperative dysphagia. It has been also reported that the risk factors for dysphagia after anterior-posterior cervical surgery were an increased number of exposed anterior levels, anterior surgery that extended above C4, and requirement of further surgical correction of C2–7 lordosis.[7,10,21,26] Total posterior cervical fusion in a flexed position may cause dysphagia.[12,29] On the contrary, a patient's age was found to have a significant effect on the risk of dysphagia, which is not surprising given that anatomical and physiological changes associated with aging predispose elderly patients to dysphagia.[7,30]

The present study suggests that there are differences between the cervical motions of the 2 postures during swallowing. In the retraction posture, an increase in posterior translation and a decrease in angular motion occurred during swallowing. Mekata et al[16] suggest that normal deglutition can be disturbed when the cervical spinal movements are restricted. In addition to this finding, our data showed that the posterior movements become larger in the retraction posture, especially in the upper cervical spine (C0, C1, and C2) than the neutral posture, which suggests that the movement of the upper cervical segments could be an important compensation mechanism for swallowing and the fixation of the upper cervical spine could be one of the risk factor of postoperative dysphagia. Moreover, C0 angle change and movement during swallowing is significantly higher in the retraction posture than in the neutral posture and C0 segment is the dominant level of compensatory motion occurred when subjects feel dysphagia in the retraction position. Therefore, if we fix up to the cranium in the retraction position, the major segment of compensatory movement cannot act properly to allow swallowing, which leads to postoperative dysphagia. So, avoiding OC fixation in retraction posture and sparing C0 segment for posterior fixation are important technical tips to prevent postoperative dysphagia.

This study has several limitations. First, the limited sample size is main drawback of our study. Nevertheless, our study showed there is a statistical significant difference between each different level of the cervical spine segment in terms of angle change and movement. These consistent results indicate that upper cervical spine is the most important level of compensation for the swallowing on retraction posture. Second, the subjects were seated upright in a chair for the duration of the study and ingested a diluted barium solution. Therefore, evaluations of other positions or using thickened food were not performed. Third, the present study analyzed only 1 swallow per posture. Therefore, the limited number of swallowing trials and individual variability remain methodological concerns. The mean values of each parameter may have been influenced by 1 swallow per posture and by the individual variability of a single subject. Finally, we investigated the influence of the neck's postural change on the cervical spinal motion and angle during swallowing only in normal volunteers who had no cervical disease. More research is needed to analyze the cervical motion and angle during swallowing in the patients with long level cervical fusion or severe cervical spondylosis.

5. Conclusion

Our study showed that the cervical spine moves to reduce physiological lordosis during swallowing in the neutral position. In the retraction posture, the posterior translation of each cervical vertebra and cervical kyphosis increases and absolute angle change decreases than they do in the neutral posture. C0 angle change and movement shows the most significant difference between the neutral and retraction positions. These data suggest that C0 angle change and movement might be the dominant segment to compensate dysphagia in the retraction posture. These results may imply that, when a surgeon performs OC fixation in the retraction position, dysphagia would be inevitable not only because the oropharyngeal space become narrow but also because the angle change and movement of C0 segment are not possible to compensate the mechanical restriction. So, it is important not to do OC fixation in retraction posture. Also, sparing C0 segment could provide some degree of freedom for the compensatory movement and angle change to avoid dysphagia after OC fixation.

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