The Role of the Pars Recta and Pars Oblique of Cricothyroid Muscle in Speech Production

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Summary: To evaluate the functional difference of the pars recta and pars oblique during speech production, the electromyographic activities of these muscles were measured in thyroidectomized patients. The hooked wire electrodes were inserted into the normal side of the bellies of the pars recta and pars oblique bundles. Two kinds of sentences were used to obtain pitch changes, a simple interrogative sentence and a complex sentence with stress contrasts. The pars recta and pars oblique were simultaneously activated for initial lengthening and tensing of vocal folds to produce speech. The pars oblique might be initially more active than the pars recta at the initial task of speech and the pars recta might be more active at the pitch elevation in the interrogative sentence and the stress contrast of the complex sentence. The maximum electromyographic activity range of the pars recta and pars oblique seemed to be nearly equal. These results demonstrated that the patterns of electrical activities of the two bellies are different during speech and the combined activities of the pars recta and pars oblique are important in the adjustment of the vocal fold length during speech. Key Words: Pars recta—Pars oblique—Speech—Thyroidectomy.

INTRODUCTION

It has been well known that the cricothyroid muscle is important functionally in pitch control during phonation and speech. This muscle is composed of three distinct bellies—pars recta, pars oblique, and pars horizontalis—named such because of their orientations to the airway axis. The contraction of the pars recta results in a decrease in the distance between the thyroid and cricoid cartilage. This is achieved by rotating the thyroid cartilage downward the cricoid in the vertical axis and results in an increase in the vocal fold length and tension. The pars oblique, on the other hand, has an additional function of moving the thyroid cartilage forward and the cricoid cartilage backward, resulting in an increase of vocal fold length and tension also.

In the study of these two movements using an excised human larynx, Vilkman et al4 reported that the rotation of thyroid cartilage on the axis of the cricothyroid joint is the most important factor affecting the longitudinal tension of the vocal folds. He suggested that this rotation at the cricothyroid joint requires proportionately greater shortening of the
pars recta than of the pars oblique and resulted in shortening the anterior cricothyroid distance and raising the pitch. Other researchers\(^5\) also found distinct movements of the pars recta and pars oblique in the cricothyroid joint. Kitajima et al\(^8\) reported on the relationship between cricothyroid distance and vocal pitch using an excised human larynx. He found that the cricothyroid distance was shortened most during stimulation of the external trunk of the superior laryngeal nerve as contrasted to the response resulting from stimulation of individual nerve branches to either the pars recta or pars oblique. Hong et al\(^9\) has reported the functional differences of these two muscles using an \textit{in vivo} canine laryngeal model. He found that stimulation of the pars recta nerve branch resulted in greater increases in the \(F_0\) values compared with that of the pars oblique nerve branch. He also found that the changes in cricothyroid distance and vocal fold length showed the same tendency as that of the \(F_0\). Sonninen\(^10\) reported that anterior movement of thyroid cartilage on the cricothyroid joint corresponds to less than 50% of the overall change in the length of the vocal folds.

On the human study, Fink and Demarest\(^5\) measured the forward movement of the thyroid cartilage using lateral neck radiographs during singing. They demonstrated that the forward movement was greatest in trained singers, less in untrained singers, and absent in nonsingers. Fujisaki\(^11\) reported that the thyroid rotation might be associated with the accent component and the forward movement of thyroid cartilage with the phrase component of speech. He proposed that the two bellies of the cricothyroid muscle work independently of each other and differ in the temporal pattern of their activities. Recently, McHenry et al\(^12\) reported the differential activity of these two muscles in \(F_0\) control in thyroidectomized patients using hooked wire electrodes. He found that the pars recta and pars oblique do not function in a similar manner, and speculated that the effect of pars recta and oblique contraction may be a function of individual anatomical variations.

This present study used living persons to evaluate the functional differences of pars recta and pars oblique during the production of speech. The patterns of electrical activity of these muscles were evaluated at the beginning of speech and during speech with stress contrast.

**SUBJECTS AND METHODS**

**Subjects**

Eight patients received ipsilateral thyroid lobectomy due to benign thyroid lesions and 2 patients received total thyroidectomy due to malignant thyroid lesions. Ages ranged from 25 to 52 years (mean 37 years old). The subjects did not have any organic and functional problems affecting voice and speech production before receiving surgery. Informed consent was obtained from all subjects, and the protocol was approved by the Institutional Ethic Board at Chonbuk National University Hospital.

**Procedure**

During surgery the strap muscles were dissected and retracted as gently as possible. After removal of the thyroid gland, both cricothyroid muscles were exposed carefully. The superior laryngeal nerves were preserved completely, dissected carefully when found, and not dissected when not found. Pairs of 44 gauge \(\times\) 100 mm hooked wire electrodes with 25 gauge \(\times\) 50 mm cannula (Nicolet Biomedical, #019-772900, Madison, Wisconsin) were inserted into the normal side of the bellies of the pars recta and pars oblique bundles under direct vision (Figure 1). The wires were secured into the muscles with loose-stitch 5.0 vicryl sutures to ensure that the electrode placement would be maintained. The wires were brought out of the side of the incision, labeled, and taped to the neck skin. Five to seven days after thyroidectomy, subjects were asked to obtain the electrical signals...
and speech signals. Nicolet II EMG system (Nicolet Biomedical, Madison, Wisconsin) was used and electromyographic (EMG) signals were passed through differential amplifiers with filters.

**Data analysis**

Data were collected on three channels: the upper channel for acoustic signals, and the lower two channels for electrical activity from the pars recta and pars oblique. EMG signals were then rectified, integrated, and smoothed using a Nicolet II EMG system programmed (Figures 2 and 3). For the speech samples, two kinds of sentences were used to obtain pitch changes, a simple interrogative sentence with stress variation and a complex sentence with stress contrasts. Subjects were asked to produce a simple sen-

![Figure 2](image1.png)
**FIGURE 2.** Acoustic and electromyographic signals, rectified, during the production of a simple sentence. Larger activation (B) of pars recta at the pitch elevation (A) of sentence terminal and larger activation (C) of pars oblique at the beginning of the sentence are noted.

![Figure 3](image2.png)
**FIGURE 3.** Acoustic and electromyographic signals, smoothed, during the production of a simple sentence. Larger activation (B) of pars recta at the pitch elevation (A) of sentence-terminal and larger activation (C) of pars oblique at the beginning of the sentence are noted.
tence (It means “good morning?”) in response to the question and a nonquestion sentence (It means “I am fine.”) (Figures 2 and 3). Subjects also were asked to speak a complex sentence with stress contrast in the middle of the sentence (Figures 4 and 5). Subjects produced these sentences at a comfortable pitch and loudness. The EMG and speech signals were recorded three to five times.

The measurement of the EMG activities of the pars recta and pars oblique were determined through

**FIGURE 4.** Acoustic and electromyographic signals, rectified, during the production of a complex sentence. Larger activation (B) of pars recta at the pitch elevation (A) in the sentence and larger activation (C) of pars oblique at the beginning of the sentence are noted.

**FIGURE 5.** Acoustic and electromyographic signals, smoothed, during the production of a complex sentence. Larger activation (B) of pars recta at the pitch elevation (A) in the sentence and larger activation (C) of pars oblique at the beginning of the sentence are noted.
visual inspection of processed and smoothed data. The slow inclination of electrical signal was defined as “mild,” steep inclination as “marked,” and gradual inclination as “moderate.” The intratest reliability was determined by repeatedly measuring the EMG activities.

RESULTS

Table 1 summarizes the patterns of EMG activity during the production of interrogative sentences. It can be seen from Figures 2 and 3 that the pars recta and pars oblique were activated simultaneously before the production of acoustic signals in all subjects and then gradually became activated with speech. The initial patterns of EMG activity during speech production were different in the pars recta and the pars oblique. There was earlier and steeper activity in the pars oblique than in the pars recta in six of the eight subjects, and no differences were found in two subjects. After initial activation, the pars recta tended to be more dynamically activated than the pars oblique as shown in Figures 2 and 3. In the interrogative sentence which contained elevated stress, the pars recta was more dynamically activated than the pars oblique in the seven subjects. The maximum EMG activity range during speech seemed to be nearly equal.

In the initial task of uttering a complex sentence with stress contrast (Table 2), the EMG signals of the pars recta and pars oblique appeared to occur earlier than the acoustic signals in all subjects and gradually activated with sentence. The EMG activity of pars oblique occurred earlier than that of the pars recta and with moderate activity in six of the eight subjects, and differences were not found in two subjects (Figures 4 and 5). However, the EMG activity of the pars recta was greater than that of the pars oblique in stress contrast production in seven of the eight subjects (Figures 4 and 5). The maximum electrical activities of these two bellies seemed to be nearly equal during speech production.

DISCUSSION

As commented by many researchers, the mechanisms of pitch regulation by the pars recta and pars oblique has been known as different on the view of biomechanical movement of cricothyroid joint. The contraction of the pars recta narrows the cricothyroid distance by the forward rotation of thyroid cartilage on the cricothyroid articulation, and results in elongating and tensing of the vocal ligament. On the oblique orientation of the muscle fibers of the pars oblique, it is responsible for the forward translation of the cricothyroid joint. However, the synergistic and cooperative effects of both these muscles are important to the pitch regulation by changing the cricothyroid distance and vocal fold length. On the functional differences between the pars recta and pars oblique, many researchers have reported that the pars recta has a greater effect on pitch regulation than the pars oblique. Vilkman\(^4\) reported that the most important factor affecting the longitudinal tension of the vocal folds is the rotational movement of thyroid cartilage on the cricothyroid joint by the contraction of the pars recta. Kitajima et al\(^8\) also found that in excised human larynges the pars recta nerve branch appears to be a more effective tensor than the pars oblique nerve branch. This would explain the dominant effect of the pars recta compared with the pars oblique in raising the pitch. On the other hand, Vilkman et al\(^3\) suggested that the pars oblique might be important in adjusting the vocal fold length by forward translation of the thyroid cartilage. Mayet and Mundnick\(^7\) also demonstrated that the forward translation of the cricothyroid articulation in a sagittal plane is possible only in certain rotational positions.

**TABLE 1. The EMG Activities in the Simple Interrogative Sentence**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Earlier activation</th>
<th>F(_2) increase (terminal)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PR</td>
<td>PO</td>
</tr>
<tr>
<td>Subject 1</td>
<td>+</td>
<td>&lt;</td>
</tr>
<tr>
<td>Subject 2</td>
<td>+</td>
<td>&lt;</td>
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<td>Subject 3</td>
<td>+</td>
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<tr>
<td>Subject 4</td>
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<td>&lt;</td>
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<tr>
<td>Subject 5</td>
<td>+</td>
<td>&lt;</td>
</tr>
<tr>
<td>Subject 6</td>
<td>+</td>
<td>&lt;</td>
</tr>
<tr>
<td>Subject 7</td>
<td>+</td>
<td>=</td>
</tr>
<tr>
<td>Subject 8</td>
<td>+</td>
<td>&lt;</td>
</tr>
</tbody>
</table>

**Abbreviations:** PR, pars recta; PO, pars oblique; +, mild activated; ++, moderate activated; ++++, marked activated.
of the joint. Sonesson\textsuperscript{6} concluded that the anterior translation of the thyroid cartilage accounted for 75\% of the vocal fold elongation associated with raising the pitch.

In this study the results demonstrated the simultaneous activation of the pars recta and pars oblique in the initial tasks of speech, but they showed distinct differences of patterns of EMG activity during speech production. The pars oblique showed an earlier and marked activation in the initial task of speech compared to the pars recta. The pars recta showed marked activation during production of the interrogative sentence and during stress contrast in the sentence. Even though we did not directly observe movements of anterior rotation and translation, we could suggest that in the initial task of speech, anterior translation of thyroid cartilage might be more dominant than anterior rotation, and anterior rotation of thyroid cartilage might be more dominant than the translation in the pitch elevation of the sentence. However, frankly speaking, we are not sure that the activation of the pars oblique always induces anterior translation of thyroid cartilage. Regarding the potential for anterior translation of thyroid cartilage as a vocal fold lengthening mechanism, it still remains controversial by reviewing the literature. Kahane\textsuperscript{13} argued strongly against the potential for gliding. He concluded from anatomical studies that the cricothyroid articular facets are oriented outward, requiring that the inferior horns be continuously separated from the cricoid cartilage to achieve significant change in vocal fold length. This movement is inhibited by the ligaments of the cricothyroid joint. This contention was supported by Mayet and Mundnick,\textsuperscript{7} who also stated that gliding would be restricted by the ligaments. Further support for the lack of gliding was provided by Stone and Nuttall\textsuperscript{14} in neural stimulation of the superior and recurrent laryngeal nerves in dogs. They reported that the data of Sonninen may be based on the cricoid artifact. With sufficient upward rotation of the cricoid arch, the superior aspect of the cricoid signet may approximate the posterior pharyngeal wall. This displacement could be misinterpreted as translation of the thyroid cartilage when attention is focused solely on this structure. By contrast, the potential for translation was supported by Maue and Dickson.\textsuperscript{15} In the dissection of excised human larynges, they found that the size, shape, configuration, and presence of the cricothyroid facets were extremely variable. In 30\%, only soft tissue facets were observed, characterized by a flat cartilage surface and no definable cartilaginous facet. In 20\%, facets were well defined bilaterally.

On the human study of these two muscles, Fink and Demarest\textsuperscript{5} demonstrated that professional singers exhibited a larger cricothyroid space on lateral radiographs than untrained singers when producing the same pitch. They also found a greater ventrodorsal gliding in trained singers than in untrained singers. Fujisaki\textsuperscript{11} also reported thyroid rotation with the accent component and the thyroid translation with the phrase component of speech. Honda\textsuperscript{16} found

<table>
<thead>
<tr>
<th>Subject</th>
<th>Earlier activity</th>
<th>Stress contrast in the sentence</th>
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<tbody>
<tr>
<td></td>
<td>PR</td>
<td>PO</td>
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<tr>
<td>Subject 1</td>
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<td>Subject 2</td>
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<td>Subject 7</td>
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<td>Subject 8</td>
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\textit{Abbreviations:} PR, pars recta; PO, pars oblique; +, mild activated; ++, moderate activated; ++++, marked activated.
that the pars oblique was more highly correlated with Fo control than the pars recta. He speculated that the pars recta may increase Fo independently of articulatory gestures and may be associated with the rapid Fo changes of articulatory gestures. However, the present study showed a higher correlation of Fo control with pars recta activity than with pars oblique activity.

**SUMMARY**

We suggest that the pars recta and pars oblique are important for initial lengthening and tensing of vocal folds to produce speech. The pars oblique might be more active than the pars recta at the initial task of speech, and the pars recta might be more active in the pitch elevation within the sentence or at the terminal part of the sentence. Unfortunately, with the marked activation of the pars oblique in the initial task, the forward movement of thyroid cartilage by the pars oblique was not documented in this study.

**REFERENCES**

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