Ann.Bull.RILP(1988)No.22, 165-172

THE PHYSIOLOGICAL ROLE OF THE STERNOTHYROID MUSCLE IN PHONATION

AN ELECTROMYOGRAPHIC OBSERVATION

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Introduction

The function of the strap muscles in speech production have been studied by several researchers[1-6]. These works agree that in general the strap muscles contribute to lower the fundamental frequency(F0), or at least they become active when the F0 becomes lower. On the other hand, there is little research concerning the functional differences among the strap muscles. We assume that this is because the strap muscles are supposed to act as a whole muscle chain. In other words, since the strap muscles run from the mental process of the mandible to the hyoid bone (geniohyoid muscle), from the hyoid bone to the thyroid cartilage (thyrohyoid muscle), the thyroid cartilage to the sternum (sternothyroid muscle) and parallel to these, the sternohyoid muscle from the hyoid bone down to the sternum, it is natural to assume that when these muscles contract, the mental process and the sternum approximate each other. Or, depending on the degree of the contraction of each strap muscle, in some instances the larynx may descend so that the fundamental frequency is lowered. However, since the location of the origin and the insertion of each strap muscle are unique for each muscle, there should be some functional differences among the strap muscles. In order to clarify the functional difference of the strap muscles, observation should be made of the more delicate maneuver, such as singing or speech.

On the other hand, looking at the dynamics of the framework of the larynx, the F0 raising mechanism is explained as follows: the thyroid cartilage tilts down around the cricothyroid joint, or the frontal part of the cricoid ring comes closer to the thyroid cartilage resulting in a longer distance between the inner front part of the thyroid cartilage and the arytenoid cartilage and, then, a higher tension of the vocal cord. It is well known that the approximation of these two cartilages is executed by the contraction of the cricothyroid muscle.

Anatomically, the approximation of these two cartilages could be performed by the contraction of the sternothyroid muscle as well as by the cricothyroid muscle, since the sternothyroid muscle attaches more anteriorly to the center of the rotation (cricothyroid joint). It is easy to imagine that when the sternothyroid muscle contracts, these two cartilages approximate and cause the same effect on the vocal cord as the cricothyroid muscle does.(Fig.1)

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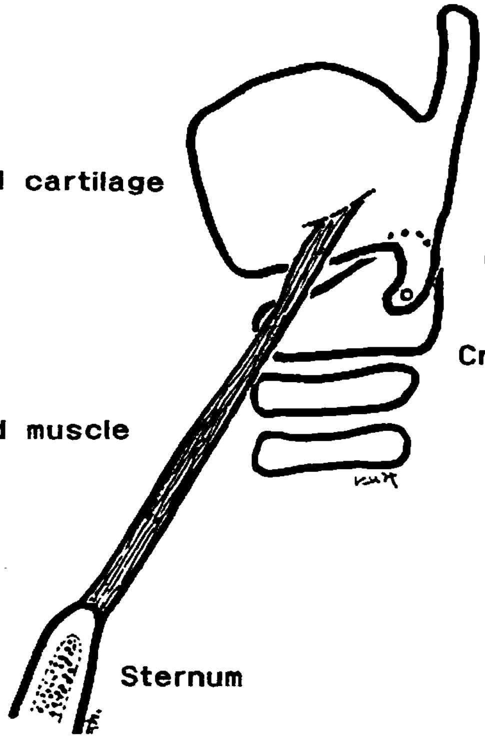

Figure 1 Schematic drawing of the anatomical relationship between the sternothyroid muscle and the cricothyroid joint.

Considering the above, we could also hypothesize that the sternothyroid muscle might act as a F0 raiser.

To test such a hypothesis, EMG signals from the sternothyroid muscle and the cricothyroid muscle were analyzed.

Method

Two professional tenor singers served as the subjects. Electromyograms (EMG) were recorded from the cricothyroid muscle (CT) and the sternothyroid muscle(ST) using bipolar hooked-wire electrodes inserted percutaneously in the neck. The electrodes were inserted as described in Hirose.[7] The locations of the electrodes were verified by various non-singing tasks such as swallowing, mouth opening, tilting of the head, elevation of the larynx and so forth. These verification maneuvers were performed several times during the recording session to make sure the electrodes stayed in the target muscles.

By using a laboratory computer, the EMG signals were rectified and aligned with a reference point which corresponded to the same acoustic event that was determined by inspection of the acoustic wave form. In this study, the reference point was chosen at the moment when the acoustic signal began to increase in amplitude. These aligned EMG signals were averaged over 6 to 9 samples so that the noise components were reduced.

The acoustic signals were recorded simultaneously with the EMG signals.

The subjects were asked to phonate a sustained vowel /a/ at a comfortable pitch , a higher pitch and a lower pitch with "normal vibrato", "rapid vibrato" and "trilla". These terms were defined by each subject.

In the present study, the trilla had two kinds of pitch changes, one labeled a 2-semitone leap and the other a 4-semitone leap. These tasks were performed in a sitting position by the subjects.

The intensity of the voice was not controlled, and the subjects were allowed to perform the tasks quite naturally.

Results

1) Non-singing maneuvers

Swallowing: For both subjects, the activity of the CT was suppressed during deglutition. The slight activity of the ST after swallowing action was observed in both subjects. For subject M.Y., the ST became active just before swallowing.

Mouth opening and closing: As expected, the ST became active for mouth opening. Greater activity was observed for /a/ production, which requires a wider mouth opening than for /i/ production. The CT showed continuous activity through the period of phonation.

Flexion of the neck: In both subjects, there was little or no activity in either channel.

Downward shift of the larynx: When the subjects were asked to shift the larynx downward volitionally, the sternothyroid muscle became active.

2) Singing tasks

Scale: Interestingly, for the singing scale, both the CT and the ST became more active for higher pitches.

Normal vibrato:

i) Cricothyroid muscle: As expected, this muscle was more active for high pitch in both subjects. There was no modulation pattern observable at any pitch in subject M.Y. On the other hand, in subject T.M., this muscle showed a modulation pattern which corresponded to the acoustic modulation.

ii) Sternothyroid muscle: This muscle was less active for low pitch than for high pitch in both subjects. In subject M.Y., no modulation pattern was observed at any pitch. On the other hand, in subject T.M., a modulation pattern was clearly seen even at low pitch, where the muscle activity became smaller.

Rapid vibrato:
Both the cricothyroid muscle and the sternothyroid muscle showed modulation patterns for the rapid vibrato. It can be assumed that these two muscles were recruited for the greater degree of modulation.

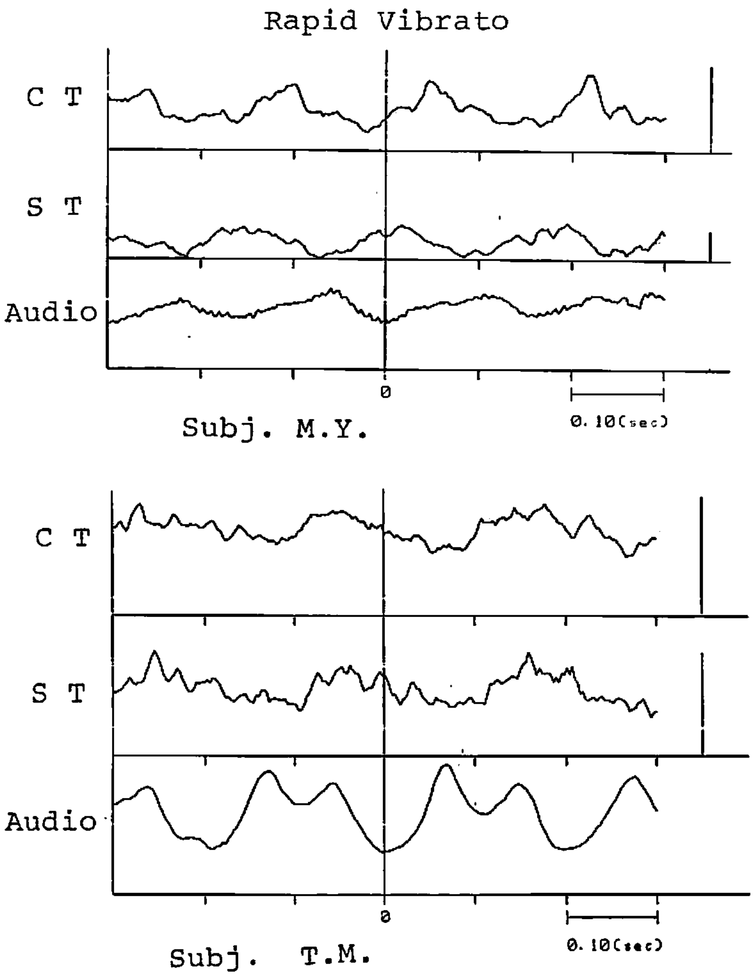

Figure 2 Electromyographic activities of cricothyroid and sternothyroid muscles in Rapid vibrato.

The vertical line on the right of each figure indicates 0.3mV as the calibration.

sternothyroid muscle became active immediately after the cessation of the cricothyroid muscle activity.(Fig.3)

On the other hand, in subject M.T., the reciprocity between the sternothyroid muscle and the cricothyroid muscle was not observed. These two muscles behaved not as antagonists but as agonists in this subject.(Fig.4)

Discussion

Since the function of the strap muscle has not been clearly understood, it is difficult to judge whether the electrodes were in the target muscle. In this study, to observe the sternothyroid activities, the electrode was inserted near the level of the lower border of the thyroid cartilage and about 1 cm laterally from the midline. When the hooked-wire electrode was inserted at this point deep enough to touch the surface of the thyroid cartilage, the active part of the electrode should have been in the sternothyroid muscle, since the distance between the needle tip and actual active site of the electrode was about 2 mm.

In this study, since the activity patterns obtained from the "ST" channel were different from those from the "CT" channel for several non-singing tasks, we could assume that there was little possibilities of the contamination from the cricothyroid muscle activity.

Another possibility of contamination is from the sternohyoid muscle activity. If the insertion site is lower than the level of the lower border of the thyroid cartilage, the electrode could be in the sternohyoid muscle, because the lower portion of the sternothyroid muscle is closely covered by the sternohyoid muscle. Although it has been reported that the sternohyoid muscle becomes active the neck flexion, the EMG activity from the "ST" channel showed little or no activity for that maneuver and marked activity for the downward shift of the larynx in this study. Judging from these unique activity patterns for various gestures, it can be concluded that the location of our electrode was in the ST.

For scale singing, the sternothyroid muscle showed greater activity for the higher F0 in both subjects. This observation suggests that this muscle plays a physiological role in raising the F0 in singing.

There could be another argument regarding the observed greater activity of the sternothyroid muscle for higher F0 production. In operatic singing, which was used in this study, the singer tries to maintain the larynx in a low position to produce the so-called "covered voice". For the production of high-pitched covered voice, it is necessary to stabilize the larynx in a lower position (by the contraction of the strap muscles) and prevent its rising, which is naturally observed in

For subject M.Y., these two muscles somehow showed reciprocity in their patterns. When one increased in activity, the other decreased. But for subject T.M., these two muscles showed activity patterns in phase.(Fig.2)

Trilla:

i) Cricothyroid muscle: Modulation patterns were present in all tasks and were marked for low pitch because of the small background EMG activity. The overall activity of this muscle depended on the pitch level, as expected.

ii) Sternothyroid muscle: As far as the modulation patterns were concerned, the EMG activity was similar to that of the cricothyroid muscle.

In subject M.Y., a reciprocal relationship was again observed between the sternothyroid muscle and the other three muscles. This reciprocity was clearly seen at high pitch. Although at low pitch the reciprocal relationship was maintained, the initiation of the sternothyroid muscle activity occurred earlier than in the case of high pitch. In other words, the

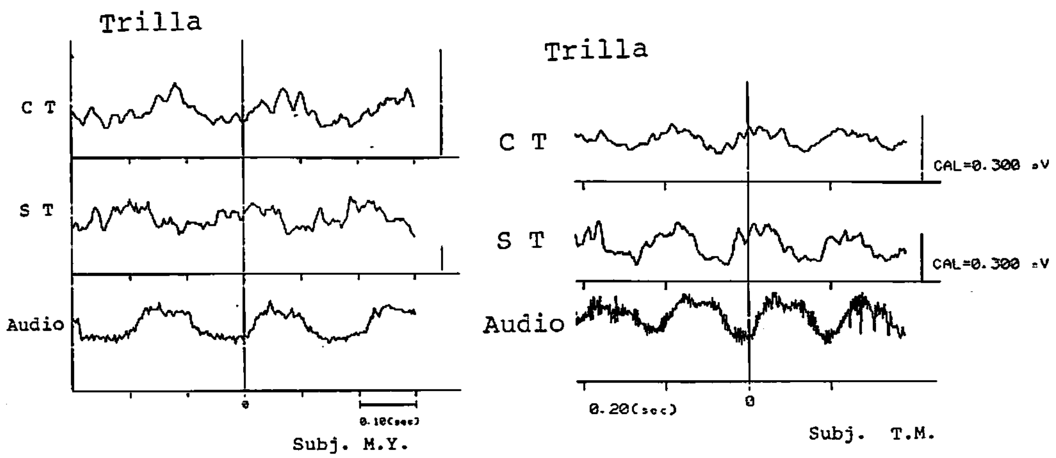

Figure 3 & 4 Electromyographic activities of cricothyroid and sternothyroid muscles in Trilla.

In subject M.Y., the reciprocal pattern of the muscle activity was observed, although not in subject T.M.
The vertical line on the right of each figure indicates 0.3mV as the calibration.

the production of a high-pitched voice. Considering the anatomical relationships and the observed higher sternothyroid muscle activity for pulling the larynx down, the contraction of the sternothyroid muscle can serve as a stabilizing force for the whole framework of the larynx.

However, even for the smaller pitch perturbation in the vibrato, for which the excursion of the larynx in the vertical dimension is smaller, the modulation pattern of the sternothyroid muscle was maintained in this study. This observation suggests that the sternothyroid muscle activity during vibrato is not for the stabilization of the larynx but for the regulation of the F0 in singing voice.

There are still some contradictions. In subject M.Y., there was an observable reciprocity between the cricothyroid muscle and the sternothyroid muscle. For normal vibrato, in subject M.Y., modulation patterns could not be observed in the sternothyroid muscle. This means that the sternothyroid muscle plays not so great a role in subject M.Y. as it does in subject T.M.

In subject T.M., the cricothyroid and sternothyroid muscles showed an in-phase activity. It is possible to speculate that the sternothyroid muscle and the cricothyroid muscle may have the same physiological role in some maneuvers in this experiment, in vibrato.

Conclusion

Although the data were taken from a small number of subjects, it was suggested that, at least singing, the sternothyroid muscle can serve as one of the pitch raisers. The mechanism of pitch raising by the sternothyroid muscle was speculated to operate as follows. When the sternothyroid muscle contracts, the thyroid cartilage tilts down to approximate to the cricoid cartilage, resulting in a higher tension of the vocal cord.

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