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Functions of Tongue-Related Muscles during Production of the Five Japanese Vowels

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Introduction

The knowledge about the function of the tongue-related muscles in speech production is essential not only for phonetic science but also to plan effective rehabilitation programs for the handicapped. However, physiology of the tongue-related muscles is not thoroughly understood because of this anatomical complexity and the lack of a suitable methodology. As we reported previously (Kumada et al.1992,Kumada et al.1993), tagging snapshot MRI is useful in investigating the function of the tongue-related muscles, especially the intrinsic lingual muscles. In this paper, we will discuss about the functional units of the genioglossus muscle and the functions of the intrinsic lingual muscles during production of the five Japanese vowels.

Method

1) Tongue configurations studied by Tagging Snapshot MRI

Using the tagging snapshot MRI, it became possible to monitor the internal structure of the tongue and its deviation from a reference position. In this study, five Japanese adults who speak the Tokyo dialect of Japanese served as the subjects. MRI images were taken at the mid-sagittal plane, 1 cm lateral from the mid-sagittal plane, the frontal plane and the horizontal plane. The subjects were asked to phonate a sustained vowel for about 2 seconds to get the tongue image. From the recorded images, we could image the contraction of the four different parts of the genioglossus muscle, the superior longitudinal muscle, the inferior longitudinal muscle and the vertical muscle of the tongue. The details have already been described by the present authors(Niitsu et al.1992) .

2) Electromyography of the tongue muscles

In order to correlate the muscle contractions and other activities, EMGs were recorded from four different parts of the genioglossus muscle. One of the five subjects was examined by EMG. In order to control the position of the electrodes to get an

EMG signal without contamination , four hooked wire electrodes were inserted vertically from beneath the mandibular triangle. By this route, the depth of the insertion, which can be controlled relatively easily, determined the target part of the genioglossus muscle (Figure 1). The EMGs were recorded in two different positions, an upright position and a supine position. The latter position was approximately the same as the position in the MRI recording. The speech tasks were the same as those of the MRI session.

Results

1) Tongue configuration and internal structure

In general, the tongue configurations for the five Japanese vowels agreed with previous studies using conventional methods. However, the inner structure of the tongue showed some differences for different subjects. Figure 2 shows these differences. In this figure, the ordinate indicates the relative length of the particular portion of the tongue in percentiles. The dotted horizontal line in each panel indicates the length at the reference position. The abscissa indicates each line which may represent a different part of the genioglossus muscle. The numbers correspond to those in figure 1.

2) Electromyography of the Genioglossus muscle

Recordings were done in both the supine and the upright position. As illustrated in the Figure 3, EMG activities were higher in the order of /i/,/e/,/u/, r.p., /o/ and /a/. This trend in the activity was consistent in both postures. However, the activity was higher in the supine position than the upright position as can be seen in Figure 4. This tendency was apparent for the perpendicular portion (GG3,4) at the supine position.

Discussion

There have been several reports on the functional units of the genioglossus. The anatomy of the genioglossus muscle suggests that the different portion contract differently to make the unique shapes of the tongue. However, there is no definite agreement on whether the genioglossus muscle can be divided discretely or whether the functional difference is gradual from portion to portion. In this study, we could not find any discrete anatomical borders which would delineate different functions. The images from the tagging snapshot MRI and EMG illustrate a gradual change in

contraction from GG1 to GG4. Interestingly, the EMG activity was higher for the perpendicular portion in the supine position. This new evidence suggests that the genioglossus muscle behaves as an anti-gravity muscle. It can be speculated that there might be a system to generate different neural command patterns according to the position of the head. This finding may also provide a suggestion for the treatment of the sleep apnea as well. As far as we know, there are few investigations of the histology of the tongue muscles. We need histological proof of the tongue muscle as a tonic muscle.

As already mentioned, the muscular structure of the tongue is too complex to investigate by EMG because of contamination from different muscles. In this study, we assume that the vertical lines and the horizontal lines in the MR images represent the intrinsic tongue muscles, that is, the verticalis, inferior longitudinalis and superior longitudinalis muscles. Then, from the MR images, we could guess the intrinsic tongue muscle activities for vowel production. The superficial line which may represent the superior longitudinalis muscle becomes short for /a/ and /o/ for which the genioglossus muscle is not very active. We can assume that the groove formation of the tongue surface might be caused by the contraction of this muscle.

From this study, we can conclude that the combination of tagging snapshot MRI and the EMG can aid in investigating not only the intrinsic structures of the tongue but also the activity of the intrinsic tongue muscles.

References

1) Kumada M,Niitsu M,Niimi S,Hirose H:A study on the inner structure in the production of the 5 Japanese vowels by tagging snapshot MRI.Ann Bull RILP,26,1-11,1992.

2) Kumada M,Niitsu M,Niimi S,Hirose H,Itai Y:A study on the inner structure in the production of the 5 Japanese vowels by tagging snapshot MRI:a second report.Ann Bull RILP,27,1-12,1993.

3) Niitsu M,Kumada M,Niimi S,Itai Y:Tongue movement during phonation:a rapid quantitative visualization using tagging snapshot MR imaging.Ann Bull RILP,26,149-155,1992.

Figure Legends

Figure 1

Schematical illustration of the electrode insertion. The deeper insertion is for the anterior portion of the Genioglossus muscle.

Figure 2

The relative length of the different portions of the genioglossus. The dotted horizontal line indicates the length at the reference position.

Figure 3

Relative EMG activity levels from different portions of the genioglossus muscle. The upper panel indicates the activity level in the supine position, the lower panel, that in the upright position.

Figure 4

The activity levels in different portions of the genioglossus muscle. The thick line indicates the activity in the supine position and the thin line indicates that in the upright position.

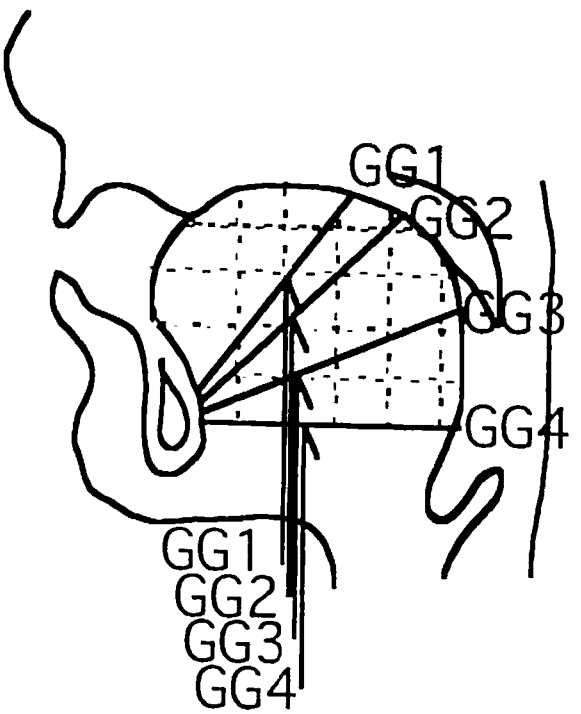
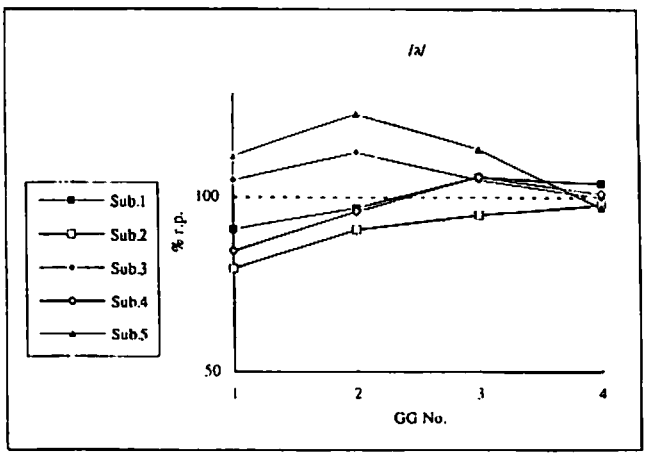


Figure 1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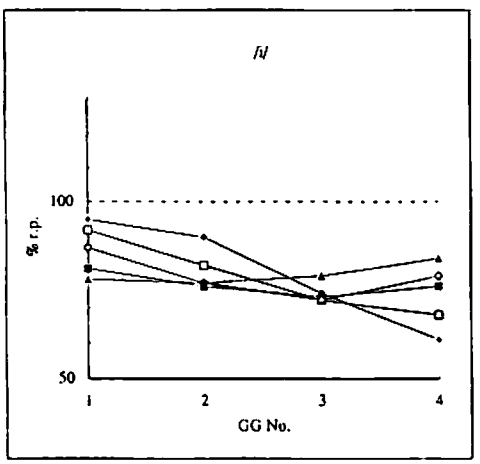
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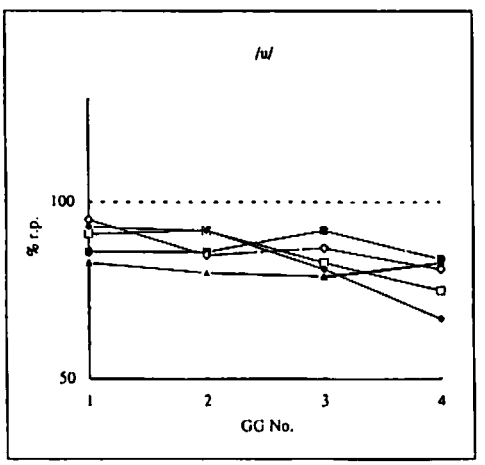
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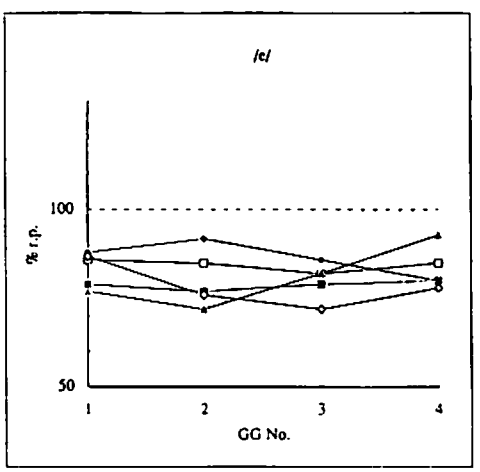
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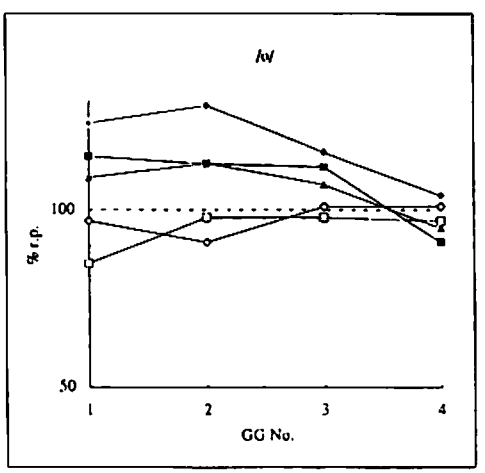
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Figure 2

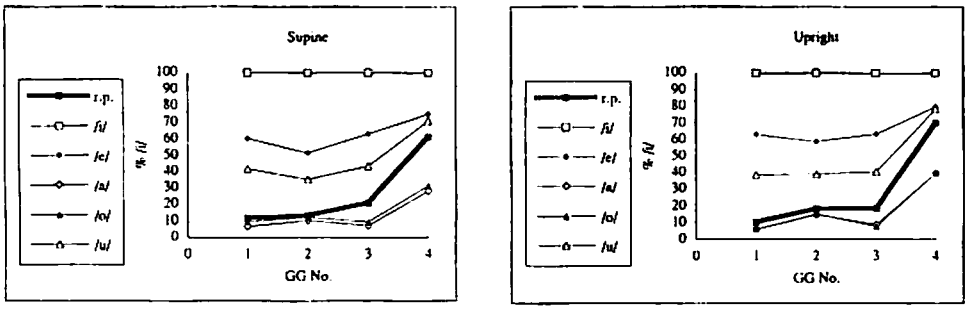

Figure 3

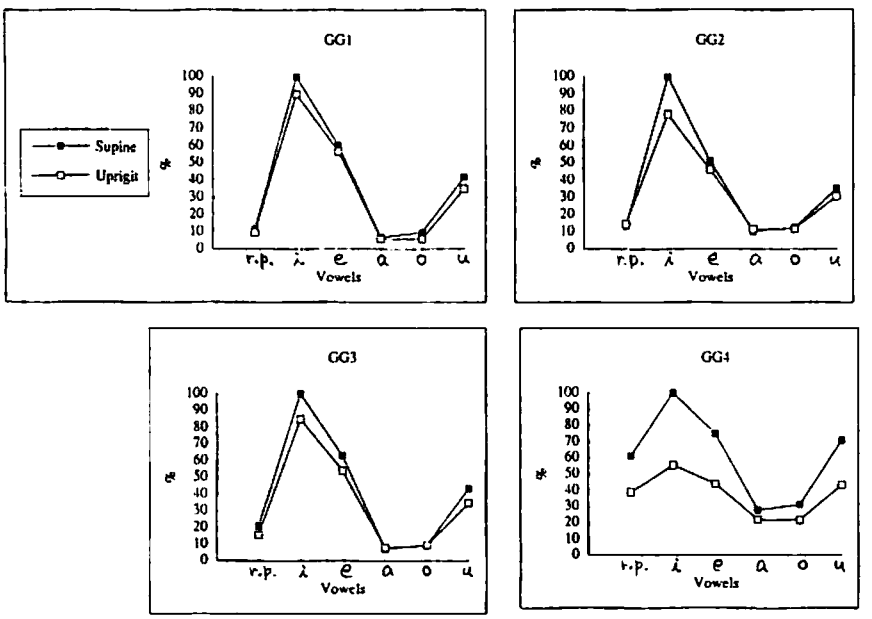

Figure 4