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Ultrasonic Observation of the Vertical Movement of the Larynx during Phonation

Atsushi Matsunaga, Seiji Niimi and Hajime Hirose

Introduction

The vertical movement of the larynx can be observed simply by the inspection of the movement of the laryngeal eminence at the midline of the neck. However, this simple and rather primitive method is not suitable for quantitative measurements. There have been several sophisticated methods developed which utilize X-rays, a mechano-optic device or cinematography which can enable a real time measurement of vertical laryngeal movements. Although these methods have provided new knowledge about laryngeal physiology, there are several difficulties. The method utilizing X-rays has problems of exposure, while the other optical methods have difficulties of calibration.

We have been developing a method to monitor the articulatory movement using an ultrasonic system. In this paper, we discuss the possibility of applying this system to monitoring the vertical movement of the larynx.

Method

The system used in this study was a linear scan type ultrasonic tomograph (RT 3000, Yokokawa Medical, Co.) whose ultrasound frequency was 5MHz. The probe for linear scan has 128 ultrasound emitting elements aligned on a straight line. Since the length of the alignment is 8cm, it is wide enough to cover the range of the vertical movement of the larynx. The device ensures a spatial resolution of 1mm, which suffices for the purposes of the present study.

In order to keep the subject stable relative to the probe, he was asked to lie on a bed in supine position with his neck extended during the experiment. A specially designed polymer-cushion (KITECKO, Sumitomo 3M) which has the same acoustic characteristics as muscles was used to allow a good contact between the probe and the skin, as well as free movements of the larynx during phonation. Since the thickness of the "KITECKO" is 5cm, it also provides a proper distance between the probe and the target, ie, the anterior framework of the laryngeal cartilages in this case. (Figure 1)

The probe was fixed against the bed with an adjustable joint. This set-

anterior skin of the neck, while the subject can still phonate naturally because of the existence of the cushion.

The ultrasonic images of the larynx were recorded on a VTR together with the subject's voice. For the measurements, the ultrasonic image was transferred to a personal computer (PC 98RL) frame by frame and displayed on a CRT monitor screen. Several measurement points were identified on the monitor scope. The coordinate values of the measurement points were stored in the computer for later analysis.

The subject was a healthy 30-year-old male who had had singing lessons for 10 years. The singing tasks used in this study are listed below.

(1) an octave arpeggio(115,144,171,225,170,143,115Hz.)without pause.
(2) an octave leap(115Hz-225Hz, 225Hz-115Hz) with a short pause between each tone.
(3) a five degree leap(115Hz-171Hz, 171Hz-115Hz) with a short pause between each tone.

Each task was performed several times in the same register and sung as the vowel /a/.

Figure 2 shows the ultrasonic image displayed on the CRT of the personal computer. The right side of the image corresponds to the subject's head. The ultrasonic shadow indicated as No. 1 corresponds to the thyroid notch, No. 2 to the cricothyroid ligament, and No. 3 to the cricoid cartilage. For the measuring points, the thyroid notch and the midpoint of the cricoid cartilage were chosen. These points are indicated by No. 4 and No. 5, respectively, in Figure 2. These two measuring points were always identifiable on every frame of the VTR.

Results

Figure 3 shows the vertical movement of the larynx and the change in the cricothyroid distance for task 1, the octave arpeggio. The abscissa indicates the vertical displacement of the larynx. In the lower panel, the ordinate indicates the distance between points No. 4 and No. 5. This distance represents the change in the cricothyroid distance. Each data point represents the average of the four repetitions. It took about 10 seconds to perform this task. It can be clearly seen that the larynx goes up, and the C-T distance becomes narrower, as the frequency increases. The average maximum displacement

of the larynx is 14mm. The C-T distance is 5mm narrower for the highest tone than for the lowest tone. It is interesting that the position of the larynx for the last tone is 5mm higher than for the first tone even when these two tones are of the same frequency. The same finding can be observed for the C-T distance. In other words, the laryngeal movement shows a trajectory with hysteresis.

Figure 4 shows the result of task 2, the octave leap, with a pause between each sound. The first data point represents the resting state of the larynx. For this task, the laryngeal behavior is basically the same as that for task 1, the octave arpeggio.

Figure 5 shows the result of task 3, the five degree leap. The laryngeal behavior is the same as above except for a smaller excursion of both movements.

Discussion

It has been known that vertical laryngeal movement during phonation is related to the fundamental frequency of voice to a certain degree. However, the physiological role of this particular movement of the larynx is still unclear partly because of the difficulty in quantifying it. Several studies have been conducted on this subject. They have used X-rays, mechano-optics and so on. Each method employed in previous studies has its strong and weak points. For example, the X-ray system cannot be used for normal subjects because of the biohazard of the X-ray exposure. On the other hand, although a mechano-optic system removes the biohazard problems, it is difficult to calibrate.

The ultrasonic system we used in this study is absolutely harmless. This means that we can obtain many data from the same subject. Beside this advantage, we can monitor the displacement of the internal structure of the larynx as well as the vertical movement of the whole structure. In this study, we could measure the change in the C-T distance.

Since the cartilages of the larynx are just underneath the skin, we had to use a kind of spacer to get the appropriate distance between the probe and the skin. The "KITECKO" support which is made of a specially designed chemical material and has been used in the clinical field was employed. A "KITECKO" of 5cm thickness was placed between the probe and the skin. It facilitated a natural articulatory movement which is essential for the natural phonation of the subject as well as for a clear image of the anterior contour of the laryn-

geal framework.

Since the ultrasonic images are recorded a VTR, the time resolution is limited to 1/60 sec. As far as the laryngeal movement for sustained phonation is concerned, this time resolution is satisfactory. The spatial resolution is as fine as 1mm. This requires the stability of the probe against the subject. In order to achieve a consistent observation, we fixed the probe to the bed on which the subject was extended. It should be noticed that in this position, the movement of the larynx is described with reference to the probe, not to the subject's body.

The data we obtained with this ultrasonic system essentially agree with those of previous reports. Our data indicate that the trajectory of the upward movement of the larynx is different from that of the downward movement. It is possible to hypothesize that one of the factors which induces this difference could be the reduced thoracic volume caused by expiration during phonation. Further investigation is now being planned to test this hypothesis.

Another interesting point of the present data is the narrowing of the C-T space. It has been proved by many EMG studies that the cricothyroid muscle contributes to pitch raising by narrowing the C-T space. In the present study, we could visualize the change in the distance. However, we still do not know how to explain the difference in C-T distances at the same pitch. We are planning to do further experiments top answer these questions.

Acknowledgements

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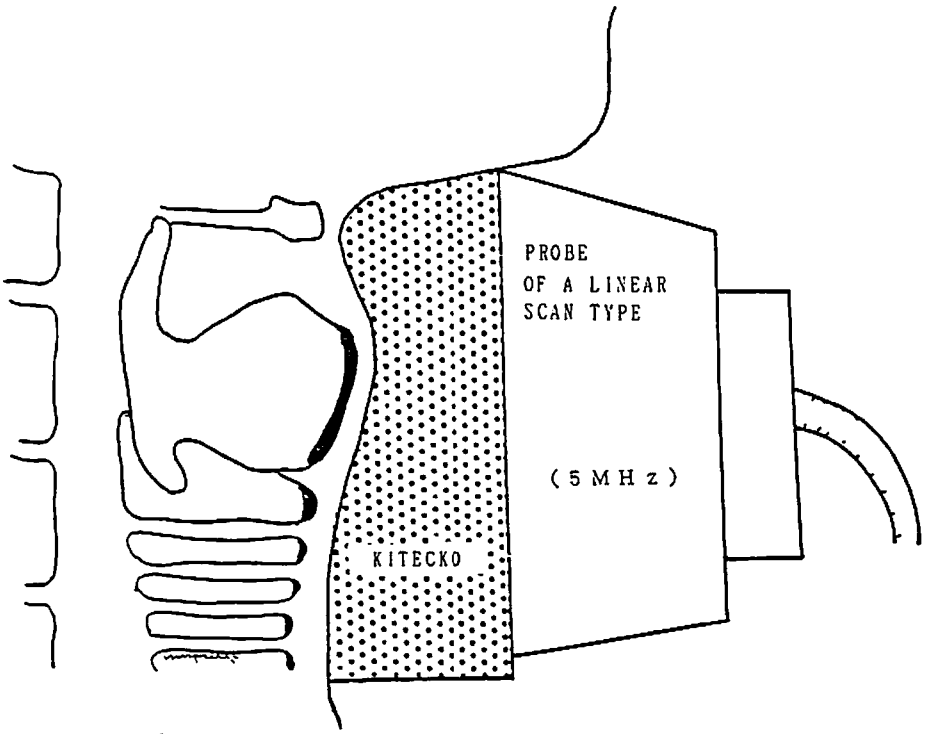

Figure 1

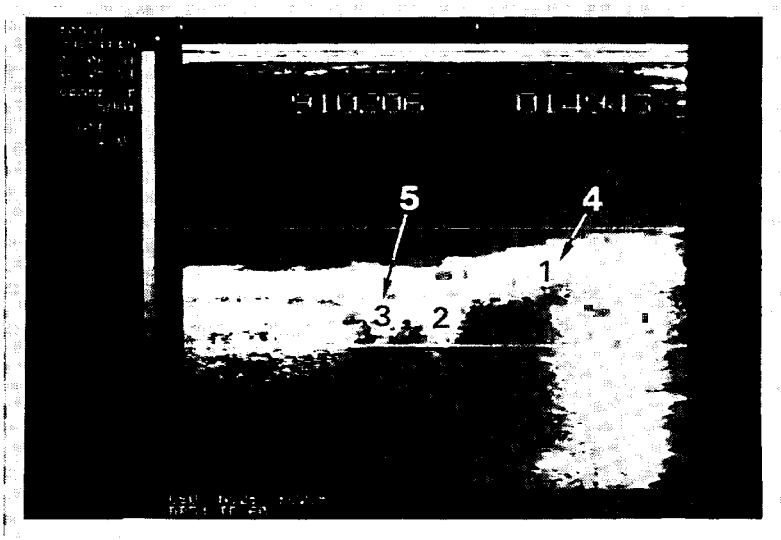

Figure 2

1: Thyroid notch 2: Cricothyroid ligament
3: Cricoid cartilage 4: The measurment point of thyroid notch
5: The midpoint of the cricoid cartilage

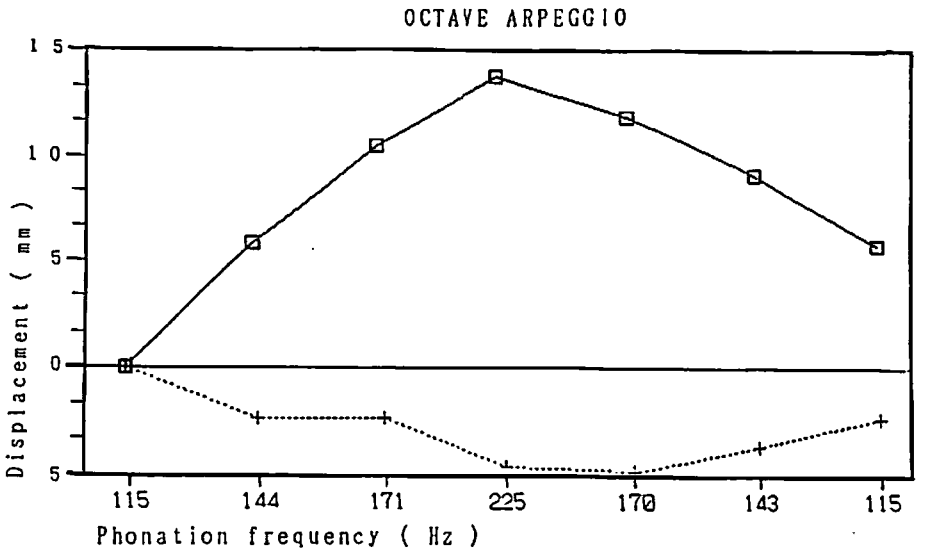

Figure 3

In the upper panel, the ordinate indicates the vertical displacement of the larynx. In the lower panel, the ordinate indicates the distance between points No. 4 and No. 5 where are shown in Figure 2. The horizontal line indicates the starting level of task 1(arpeggio).

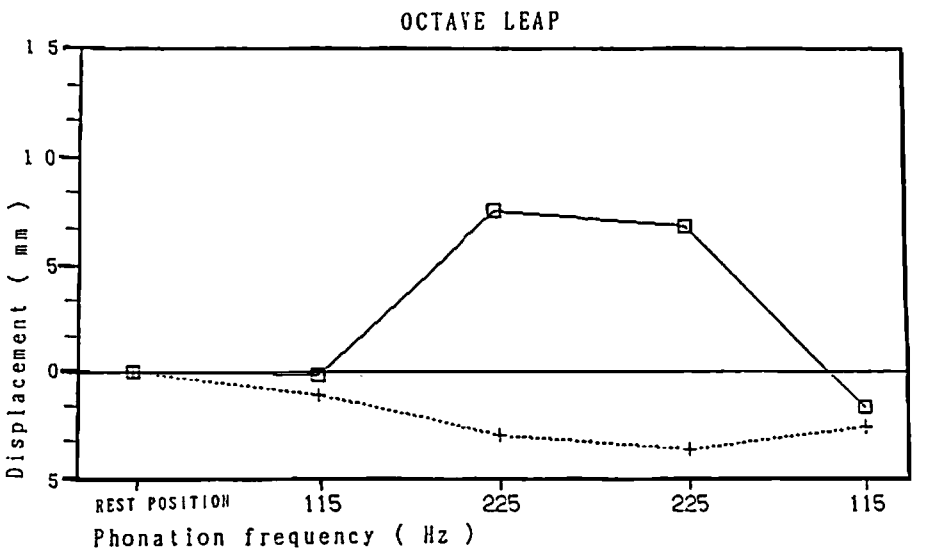

Figure 4

The indications of the ordinate is the same as figure 3. The rest position of the ordinate is resting position before phonation.

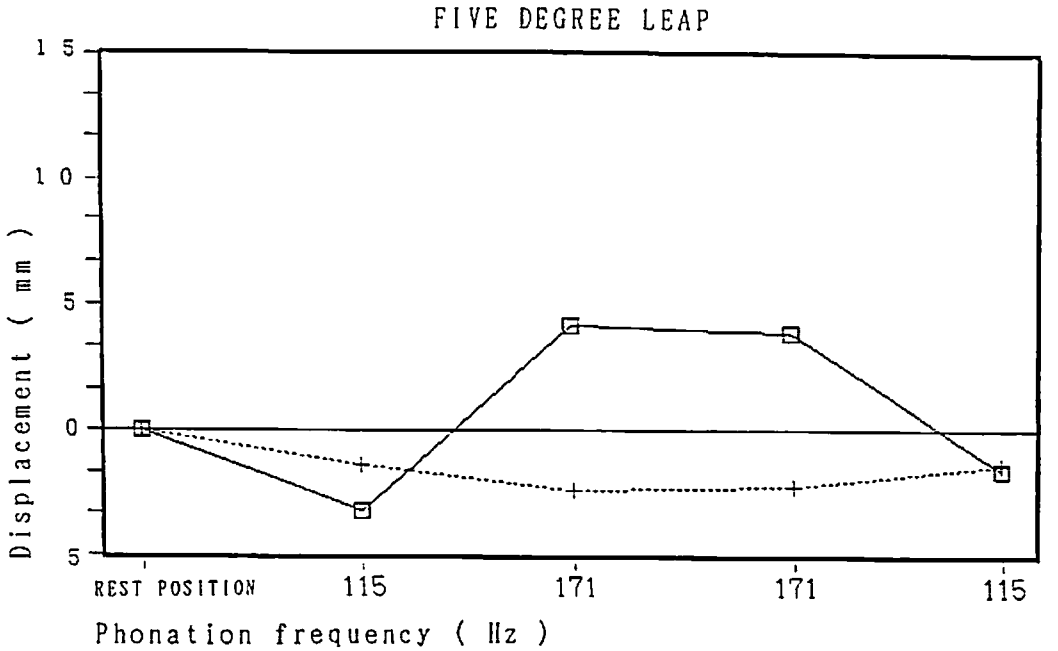

Figure 5

The indications of the ordinate is the same as figure 3. The rest position of the ordenate is resting position before phonation.