Ann.Bull.RILP(1985)No.19, 21-27

ULTRASONIC OBSERVATION OF THE TONGUE WITH REFERENCE TO PALATAL CONFIGURATION

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Introduction

Observation of the configuration and dynamics of the tongue during speech is one of the major interests in speech science and speech pathology. Several studies on this subject have been conducted. Methodologically, most of these studies have utilized X-ray techniques. Although these techniques can provide data on tongue configuration and dynamics, they have serious limitaions. One of the disadvantages of the X-ray technique is the fact that excessive X-ray exposure produces unfavorable biological side effects.

Recent advances in technology make it possible to use ultrasonic devices for studying speech physiology and pathology. Although biological side effects of ultrasonic radiation are still under discussion[1)], as far as the energy level used for diagnostic purposes is concerned, there have been no apparent side effects.

Using the ultrasonic technique, we have reported on the tongue configuration in the midsagittal and frontal planes during vowel articulation[2,3,4)]. For these observations, the probe to emit the ultrasonic pulse train and detect the echo signals was held under the subject's submandibular triangle. The ultrasonic pulse train was radiated toward the tongue surface from the submandibular region and the echo signals were reflected at the bounrary of the muscular tissue of the tongue and the air space of the oral cavity.

Since the ultrasonic device detects the deflection of the ultrasonic beam, the timing delay of the emission and the reception of the echo, the tongue configuration can be displayed in two dimensions on a CRT screen. The visualized image of the tongue using this method is greatly dependent on the angle and position of the probe against the subject's cranium. In order to know the tongue shape with reference to toher structures such as the hard palate, it is necessary to know positional information about the probe, or at least, to monitor the positional changes of the probe.

Since the ultrasonic pulse train emitted from beneath the subject's submandibular region is mostly reflected at the boundary of the tongue tissue and the air space in the oral cavity, it is impossible to visualize the palatal configuration with the tongue shape. For steady state observation, the visualization method for the facial contour and the hard palate has been reported[5)]. Acording to this report, there were some difficulties in observing tongue dynamics with the surrounding structures.

We have developed an observation system for the tongue dynamics with reference to the hard palate.

Method

In order to measure the tongue configuration against the cranium, it is necessary to know positional information about the ultrasonic probe during observation. For this purpose, a latral view of the subject with the probe was recorded using VTR simultaneously with the ultrasonic recording.

i) Measuring the position of the ultrasonic probe (Fig.1).

The lateral view of the subject's face with the probe was recorded using VTR simultaneously with the ultrasonic observation. The ultrasonic image was also recorded with a different VTR system. In order to relate these two different VTR systems unique codes generated by a code superimposer were fed to both VTR systems.

During the recording sessions, two reference points should be painted on the subject's face. Immobile sites on the face should be selected for references. In the present study, the lateral surface of the nasal ridge and the preauricular region were selected. The actual procedures were as follow;

1) · The tongue image produced by the ultrasound recorded with VTR and the corresponding VTR which contained the lateral view of the subject were transferred to a videodisk.

2) A particular field of the lateral view VTR was displayed on the CRT via image memory.

3) The position of the probe was determined against the two reference points on the subject's face. This was done by using a digitizer installed in the image processing system. The positional information was stored in the memory of the computer in digital form with the field identification code.

ii) Measurement of the ultrasonic image

The probe used in the present study scans electronically by sector. The frequency was 3.5MHz.

On the monitor CRT screen, a 1cm scale is displayed with the tongue image. This scale can provide a magnification factor of the visualized tongue for the actual structures.

Since we had numerical coordinate data of the probe against the cranium, we could superimpose the particular structure of thecranium on the ultrasonic tongue image at the proper position.

iii) Determination of palatal shape and position

In general, one of the most interesting reason for studying tongue shape is to know the vocal tract shape. For that, it is preferable to have palatal information with the tongue shape.

As stated above, the ultrasonic pulse train radiated from beneath the submandibular region could not reach the palatal surface. This means that the palatal shape could not be visualized by the ultrasonic method. To overcome this problem, a specially designed palatal prosthesis was used (Fig.2). The prosthesis was made of a special plastic sheet (New Polycast, Tokyo Eizai) which gains plasticity at 60°C or higher and becomes rigid at body temperature. A fine stainless rod of known length was attached in front of the prosthesis. It served as the reference length for the superimposition. The shape of this prosthesis was digitized by a photo and digitizer. The digitized information about the prosthesis was stored in the computor for late analysis.

Prior to the actual recording session, the subject was asked to put on the prosthesis and was photographed laterally. The photograph had to have two reference points on the lateral surface of the nose and preauricular region and the stainless steel rod projecting from the subject's mouth.

Since the palate is part of the cranium, once we know the positonal relationship between the palate and the immobile reference points on the face (in this case, the lateral surface of the nose and the preauricular point), we can consider the two reference points to represent land marks of the palate. Figure 3 shows the visualization system used in this study.

Experiment

An adult male speaker of Tokyo dialect served as the subject for this preliminary study.

The frequency was 3.5MHz. and the electronical sector scan type probe was used. The probe was held beneath the subject's submandibular triangle to emit the ultrasonic pulse train toward the tongue surface and to receive the echo signals. The tongue shape was monitoered by a B-mode displasy and recorded with VTR. In order to hold the probe stable, we used the specially designed head gear shown in Figure 4.

The tongue shape during pronounciation of the five Japanese vowels was monitored and the tongue dynamics during the utterance of three syllable words were analysed.

During recording session, the positional changes in the probe were also measured.

Results

1) Positional changes in the probe

Figure 5 indicates the positional changes in the probe were analysed against the stable points of the cranium (in this case, the lateral surface of the nose and the preauricular skin). The duration of the recording session was about 3 minutes. From this observation, it can be concluded that the range of the positional changes in the probe was up to 8mm in all directions, even with the probe holder (head gear).

2) The tongue configurations

The tongue shape and the palate observed by the present system are illustrated in figure 6. Each straight line represents from right to left; the boundary between the soft and hard palate; the highest point of the palate; the midpoint between the highest point of the palate and the root of an incisor; and the root of an incisor and the incisor. These were defined by the shape of the palatal prosthesis.

3) Tongue dynamics during the utterance of CVC syllables

The distance between the tongue surface and the palate was measured on the CRT display along the predetermined reference lines mentioned above. Then each measurement point was re-plotted. Figure 7 illustsrates two examples of the measurements. Timing was determined by inspecting the auditory signals recorded simultaneously with the ultrasonic images.

Discussion

Recently, ultrasonic imagiang has been improved and become popular because of its safety, non-invasiveness and covenience. The principle of this imaging is to measure the interval between the emission of an ultrasonic pulse and the reception of the echo signals reflected at the boundary between two acoustically different media. In the case of observation of the tongue, this reflection occurs at the tongue surface. The spacial resolution is a funcion of wave length of the ultrasound and the propagating velocity within the tissue. In this study, the frequency was 3.5MHz. Since the propagating velocity of ultrasound in muscular tissue has been reported 1500m/sec., the spacial resolution could be assumed as 0.8mm. Considering this delicate resolution, the probe should be kept as stable as possible.

On the other hand, if the probe is kept stable against the subject, the articulatory movement of the jaw might be disturbed and, also, the tongue shape might be distorted by the pressing of the probe. From the present observations, the range of the positional variation in the probe was measured as much as 8mm, even with the head gear type probe holder. Compared to the resolution of the system, 8mm was big enough to be adjusted. For this adjustment, we utilized two imaging systems. One was an ultrasonic imaging system, and the other was an outer VTR system to monitor and detect the movement of the probe. This was time consuming and not quite accurate. We are planning to replace the outer VTR system by a PSD system, since the information we need to adjust the palate shape is a coordinate of the probe against the cranium.

When we are able to develop an ultrasonic observatiaon system fitted with a PSD system, on-line imaging will be possible for use in various fields besides speech science. One of the applications will be to use it as a training tool for handicapped persons.

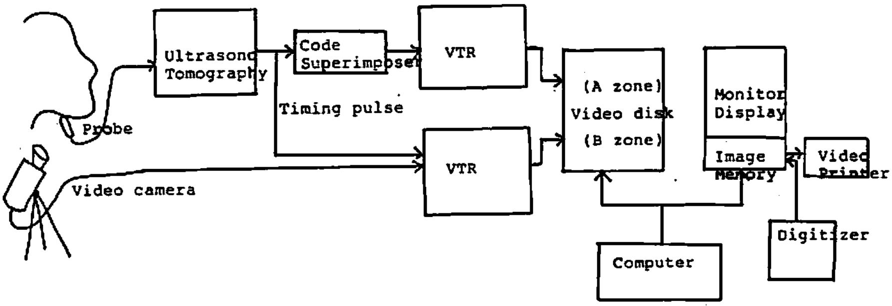

Fig. 1 Block diagram of the experimental setup.

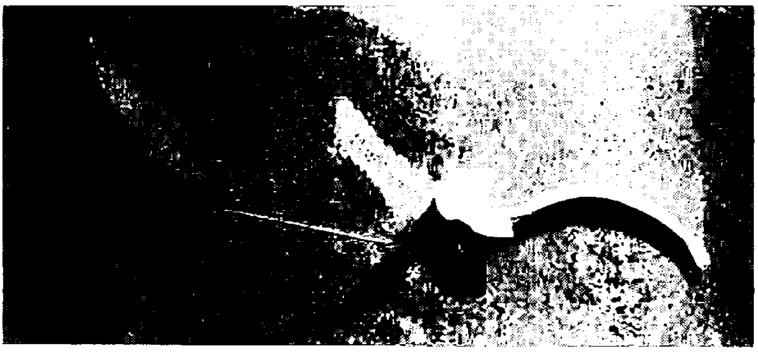

Fig. 2 Palatal prosthesis.

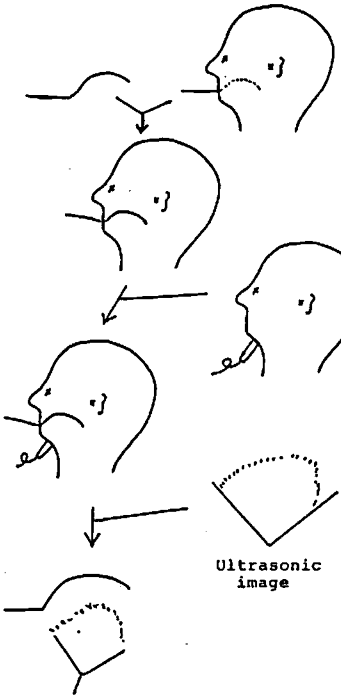

Fig. 3 Schema of the system.

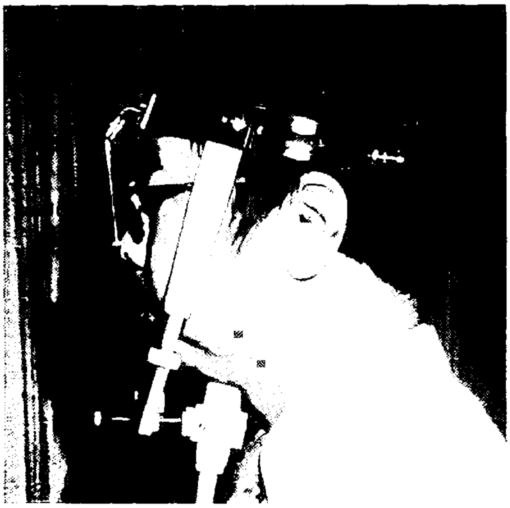

Fig. 4 Head gear.

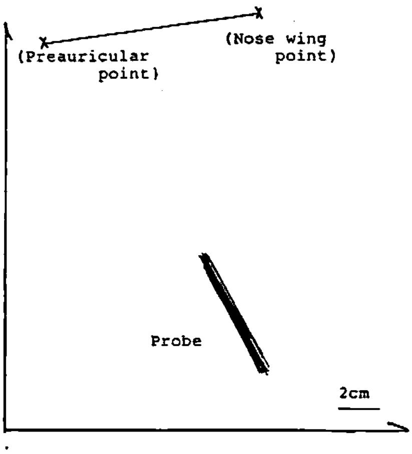

Fig. 5 Variation in the position of the probe relative to the fixed points on the face.

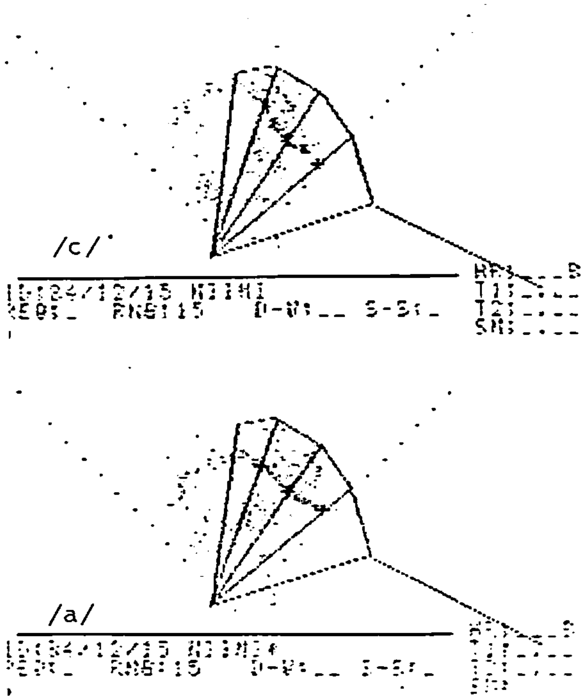

Fig. 6 Tongue shape observed by this system.

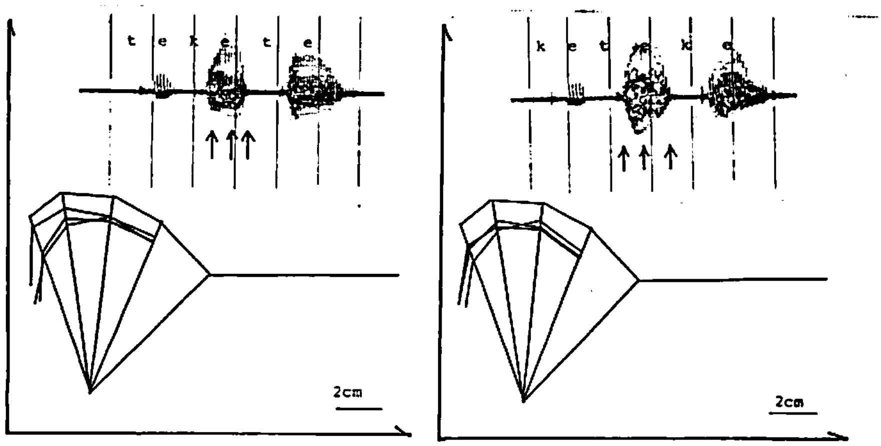

Fig. 7 Tongue configuration at the selected frames in the utterances /ket/ and /tek/.

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