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ULTRASONIC OBSERVATION OF TONGUE DYNAMICS

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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. Several studies on this subject have been published. Methodologically, most of these studies have utilized X-ray techniques. Although these techniques can provide data on tongue configuration and dynamics, they have serious limitations. One of the disadvantages of X-ray techniques is the fact that excessive X-ray exposure produces unfavorable biological side effects. This problem has been reduced by the development of the X-ray microbeam technique to track lead pellets attached to the tongue surface[1]. However, even with this sophisticated technique there are some remaining problems. Interference by such radio-opaque structures as the mandible, cervical spine, teeth, etc. limits the usefulness of radiographic techniques.

Although palatographic data may provide some insight into the configurations of the tongue, this measurement can only provide indications of contact between tongue and palate, and therefore cannot provide measurements of vocal tract shape.

In 1969, Kelsey et al suggested[2] the usefulness of an ultrasonic technique in speech research because of its harmlessness. Since then, several studies utilizing the ultrasonic technique have been published[3,4,5,6,7,8,9]. We have reported[6] on the ultrasonic observation of the frontal configuration of the tongue, as well as of the sagittal section, during production of the five Japanese vowels. In that report, we used a linear type probe to visualize the tongue surface configuration for the test vowels, Observation was limited to the static state of the tongue.

In this paper, we will demonstrate some dynamic measurements of the tongue surface during speech.

Method

Apparatus

The system used in this study consists of an ultrasonic cardiogram (UCG) system (Toshiba SAL-80) and a video-recording system to monitor the tongue movements. (Fig. 1) The probe to emit the ultrasonic pulse train and detect the echo signals is of the sector type with a 90° view angle which scans electronically. The probe was held under the subject's submandibular triangle to observe the sagittal configuration of the tongue dorsum.

The frequency of the ultrasonic beam used in this study was 3.5 MHz. Since the contact area of the probe was small (2x2cm), the subject seemed to have no problem uttering the speech samples.

Using this system, actual tongue movements can be monitored on a video-screen, and tongue dynamics along two selected axes can be printed on recording paper.

Subject and test words

A native Japanese male speaker served as subject. Test words were nonsense three syllable words with syllubles, such as $/V_1V_2V_1/$,$/V_1pV_2V_1/$,$/V_1bV_2V_1/$ and $/V_1QV_2V_1$ framed by "sono----- omiru". V_1 and V_2 were i,e and a. Thus, the actual utterances were /sono aia omiru/, /sono apia omiru/, /sono abia omiru/, /sono aQpia omiru/ and so forth. The five Japanese vowels /i/, /e/, /a/, /o/ and /u/ were also tested.

Results

The configurations of the tongue surface along a sagittal section for the five test vowels are shown in Fig. 2 . For the front vowels /i/ and /e/, it can be clearly seen that the tongue root moves forward. On the other hand, for the back vowel /o/, the tongue root moves posteriorly, narrowing the pharyngeal cavity. These observed tongue shapes and positions are consistent with those obteined by previous radiographic observations.

Figure 3 shows examples of the observed movement of the tongue. The up and down movements of the tongue along two different axes are illustrated by the upper two traces. The audio signals are shown at the bottom. The utterances shown in this figure are /sono aia omiru/, /sono abia omiru/, /sono apaia omiru/ and /sono aQpia omiru/. Movement patterns are essentially the same for /aia/, /abia/ and /apia/. In other words, the bilabial stop consonants /p/ and /b/ have no apparent influence on the movement pattern of he tongue. During the closure period for the bilabial stops, the tongue moves for the gesture of the following vowel (in this case, the following vowel is /i/). This is clearly seen in the utterance /aQpia/. These characteristics of the dynamics of the tongue are consistent with the other utterance sets.

In order to correlate the acoustic and movement data, the formant and tongue movement patterns were put together along the same time axis. (Fig. 4) It can be clearly seen that the time course of the acoustic data corresponds well to the tongue movement as expected.

Discussion

Safety of ultrasonic devices: Safety is one of the greatest advantages of the diagnostic ultrasonic device. But it is also true that the ultrasonic technique has been used to create lesions and destroy tissue. However, the power levels used for such purposes are more than 10000 times greater than that of a diagnostic system. The report from WHO[10] indicates that there have been no apparent side effects for this method. The safety of the ultrasonic method as a diagnostic tool has been tested, especially in obstetrics and gynecology[11]. The conclusion of all such test studies is that diagnostic ultrasonic system (frequency;1-10MHz, power level;less than 10miliwatt/cm^2) are absolutely safe and pose no risks or genetic side-effects to subjects.

Limits and possibilities of the ultrasonic technique: Since apparatus used in this rather preliminary study was designed and developed purely for clinical purposes, the unformation we could get has been limited. One of these limits is that we cannot visualize the palatal configuration on the same frame. Since the ultrasonic beam is radiated from beneath the tongue, the echo of the beam comes back from the tongue surface and the beam does not reach the palatalsurface. But when the subject makers a tight contact of the tongue with a foamy plastic sheet on the surface of the palate, we should be able to demonstrate the configuration of the palate.

Another limit of this system is the frame rate. The frame rate in our study was 30frames/sec. The probe we used in this study radiates 256 beams per frame. If we can reduce the number of beams, there is a possibility of improving the frame rate.

In conclusion, the ultrasonic technique can be a useful device for speech research, and can also be used as a bio-feed-back system for patients with articulation problems.

References

1. Kiritani,S. et al (1973); Tongue pellet tracking by a computer controlled X-ray microbeam system, J.Acoust.Soc.Am.,57,1516-1520.
2. Kelsey,C.A. et al (1969); Application of ultrasound in speech research,JSHR,12,564-575.
3. Minifie,F.D. et al (1971); Ultrasonic scans of the dorsal surface of the tongue,J.Acoust.Soc.Am.,49,1857-1860.
4. Watkin,K.L. and Zagzebski,J.A. (1973); On-line ultrasonic technique for monitoring tongue displacement, J.Acoust.Soc.Am.,54, 544-547.
5. Watkin,K.L. et al (1978); An ultrasonic EMG transducer for biodynamic research,JSHR,21,174-182.
6. Niimi,S. and Simada,Z.(1980); Ultrasonic investigation of tongue shape, Jpn.J.Logopedics and Phoniatr.,21,121-125.
7. Sonies,B.C. et al(1981); Ultrasonic visualization of tongue motion during speech, J.Acoust.Soc.Am.,70,683-686.
8. Keller,E. and Ostry,D.J.(1983); Computerized measurement of tongue dorsum movements with pulse-echo ultrasound, J.Acoust.Soc.Am.,73,1309-1315.
9. Parush,A. et al(1983); A kinematic study of lingual coarticulation in CVC sequences, J.Acoust.Soc.Am.,74,1115-

1125.
10. WHO(1982); Environmental health criteria 22 ultrasound, Geneva.
11. Maeda,K. and Murao,F.(1975); Review on the safety of ultrasound in clinical diagnosis and studies on cultured cells after ultrasonic irrqdiation,Cho-onpa Igaku,2,135-143.

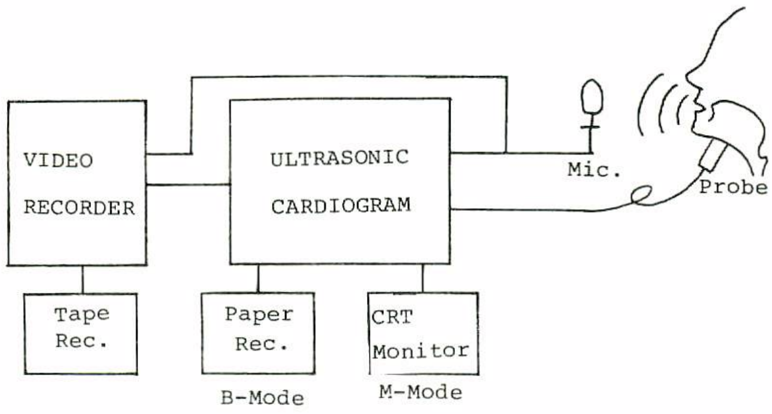

Fig. 1: Block diagram of the ultrasonic system.

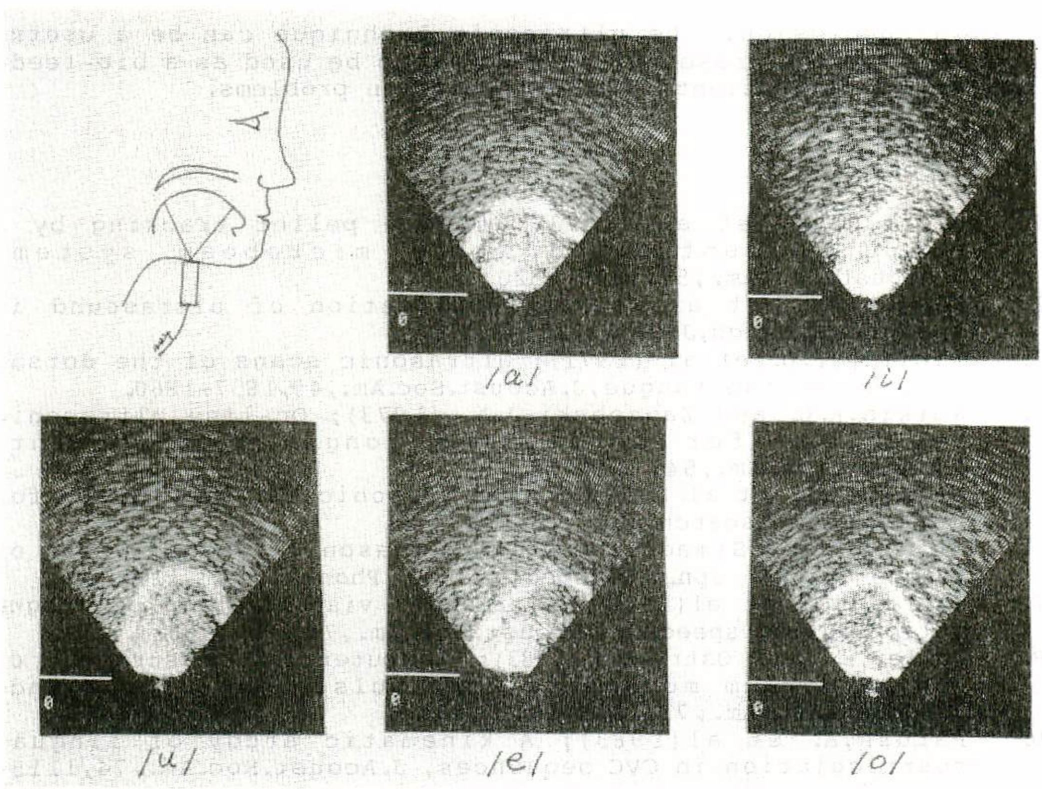

Fig. 2: Tongue dorsum shapes for the five Japanese vowels.

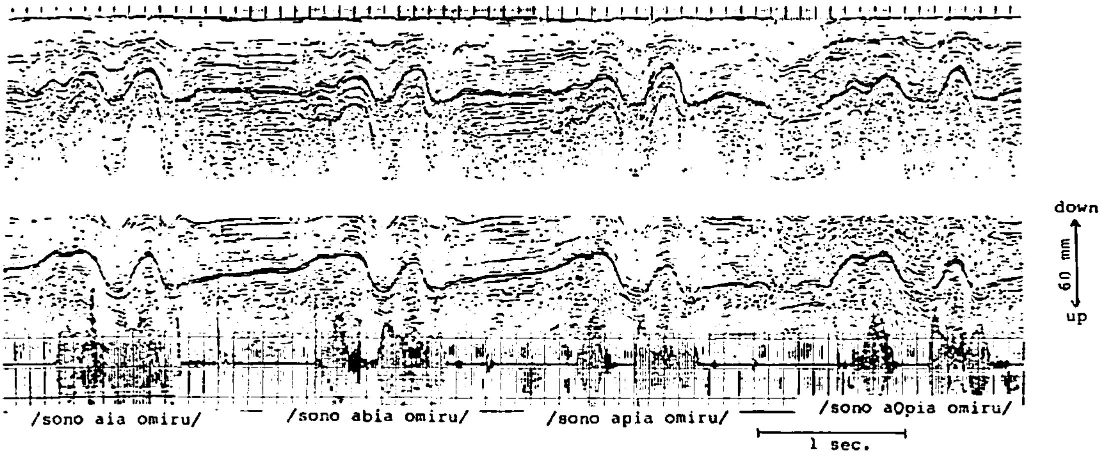

Fig. 3: Actual output patterns for the movement of the tongue. Utterances are, from left to right, /sono aia omiru/, /sono abia omiru/, /sono apia omiru/ and /sono aQpia omiru/.

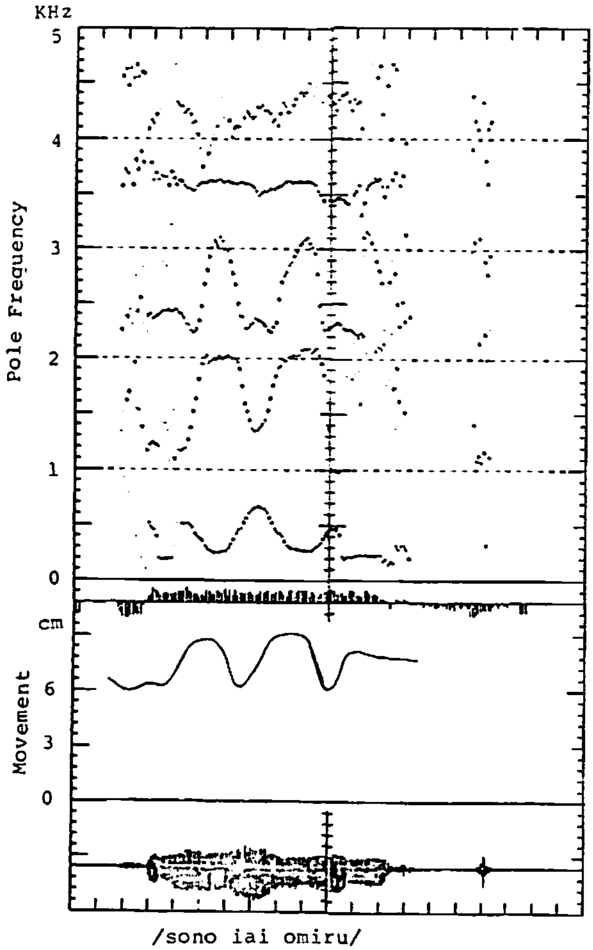

Fig. 4:

Formant and movement pattern of the tongue dorsum for the utterence /sono iai omiru/. 0 cm line at the bottom represents the level of the skin beneath the mandible.