Ultrasound Observation of Vowel Tongue Shapes in Trained Singers

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Successful ultrasound observations of consistent and recognisable tongue shapes for the Italian pure vowels a, e, i, o, u are reported. The observations were made through the floor of the mouth, perpendicular to the tongue length, with a suitable transducer. This technique may be useful in research into singing, wind instrument playing, and possibly to sleep apnea and speech therapy.

1. Introduction

Speech therapists regularly use low intensity X-rays for vocal tract examination, but ethical approval for research, using this technique, on singers and wind instrument players is difficult to obtain. This is not the case for ultrasound, because of its non-invasive nature. Ultrasound is highly attenuated by air in the adult vocal tract, so images through the cheek cannot be obtained as they are by X-rays. However, the tongue is the major articulator, and the tongue-air interface is highly reflective to ultrasound. The aim of this study was to observe tongue shapes with a suitable transducer and compare the images obtained with results from previous studies using x-rays: see [1].

2. Subjects and Method.

Trained male singers (two tenors and a baritone) were chosen for this pilot study, because of the expected ability of the singers to reproduce constant pitch and constant vowel pronunciation (i.e., tongue shapes). The vowels chosen for their well known tongue shapes were the *Italian* a, e, i, o, u. A comfortable pitch for the subjects in their middle vocal ranges was determined to be F3 (175 Hz), produced by an electronic keyboard prior to vowel utterance. Each vowel was vocalised three times for a period of approximately ten seconds and during each vocalisation an image acquired. The images were obtained in the coronal (transverse) and sagittal (longitudinal) planes: only the sagittal results are reported. The sagittal image was obtained in the midline, using the lingual septum of the genioglossus muscle as the landmark: the transducer was placed on the infraoral surface of the chin approximately 1 cm posterior to the mandibular symphysis [2]: see Figure1. The landmark was readily identifiable, and the placement was reproducible permitting the tongue shape to be defined.

The equipment used was a Philips 5000 (from Philips Medical Systems). The transducer was a P 5-3 phased array, operating at 4 MHz. The factory default setup for cardiac imaging was used to provide high contrast resolution and frame rates.

3. Results

For brevity, only the results of the ‘e’(forward), ‘u’(back) and ‘a’(centre) tongue positions for the baritone are shown Figure 2, a, b, and c. These can be compared to the shapes shown in Figure 3 [1] previously obtained by X-rays.The

other subjects showed similar recognisable tongue shapes for the vowels.

4. Discussion

While more detailed work needs to be done with a larger sample size results of this pilot study may be extrapolated to research into singing, wind instrument playing and other fields such as speech therapy and sleep apnea, .

This technique has obvious advantages of X-Ray imaging in being non-ionising, readily available and cost effective. In order to obtain reproducible images in a variety of subjects the sonographer will require training in the anatomy of the soft palate.

5. Acknowledgements

Thanks are due to Dr. Imants Svalbe (Physics) for helpful discussions and constant support of this project, and to Mr. Peter Coombs (Now Monash Medical Centre) for discussions and some early experimental trials. The late Dr. Peter Clinch, clarinettist, who examined tongue shapes in clarinet playing for his Ph.D.(Monash) [3] in the early 1980's, held great hopes for using ultrasound in this area, to help students and professionals. It is now possible!

References

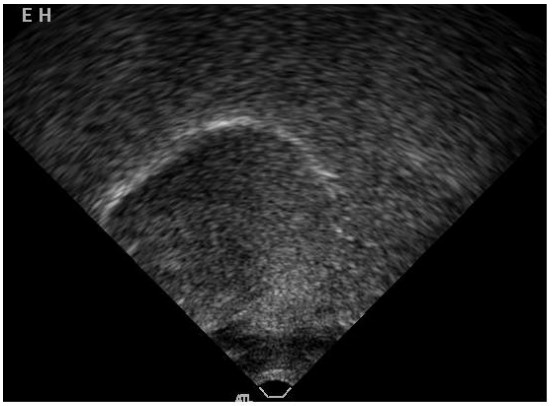
[1] P. Ladefoged, *Elements of acoustic phonetics*, (U. of Chicago Press, Chicago 1962).

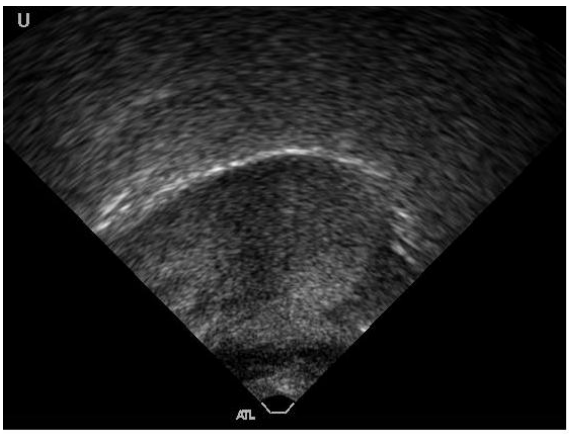
[2.] K.L.Moore and A.F. Dalley *Clinically oriented anatomy*, (Lippincot and Williams, 4th ed. 1999) p935.

[3] See P. G. Clinch, G.J.Troup and L.Harris, Acustica **50,** 280 (1982).

Figure Captions

Fig.1. Placement and beam axis direction of the transducer.





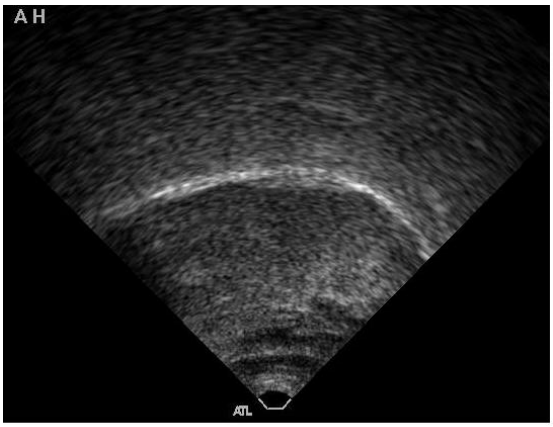


Fig.2. Tongue shape images for the baritone: (a), ‘e’; (b), ‘a’; (c), ‘u’.

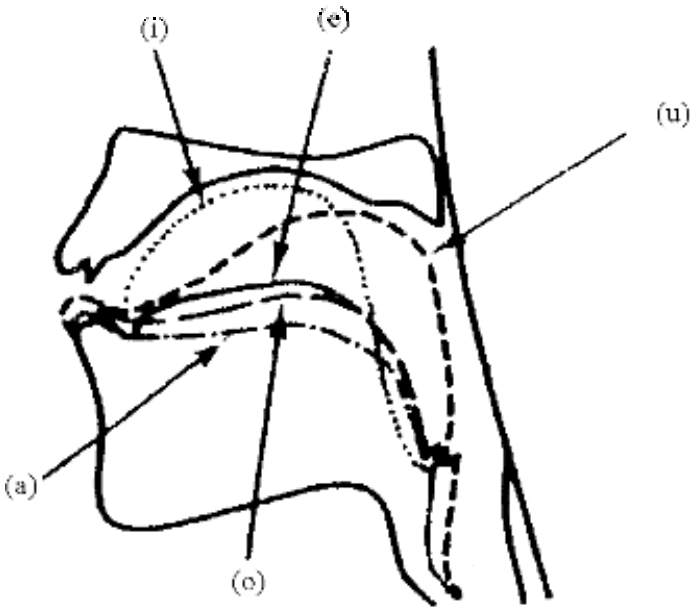


Fig.3. Tongue shapes for the *Italian pure* vowels from X - rays (Ladefoged [1]).