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Posterior Tongue Grooving in Deglutition and Speech: Preliminary Observations

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Abstract. Real-time ultrasound sector scanning was used to image the posterior tongue. Depth of tongue grooving and distance of the tongue surface from the transducer face were measured in 7 normal subjects, for vowels in a standardized speech context and for dry swallows. Tongue postures for the vowels |æ| or |e| were most similar to the maximum grooving found in deglutition, which occurred approximately 300 ms prior to ultrasound evidence of initiation of the reflexive pharyngeal phase of swallowing.

Key words: Deglutition – Tongue groove – Speech, normal.

Physiological research on the mechanisms of speech and swallowing has existed for decades and even uses some common methodologies. The focus and research issues in the two areas are very different, however, and this has discouraged detailed physiological comparisons between the two activities.

Grooving of the tongue is an example of a functional requirement common to both deglutition and speech that has received relatively little research attention. Posterior tongue grooving appears as part of the oral phase of normal swallowing [1, 2], during which a liquid is channeled centrally and moved backward to the pharynx. Until recently, the grooving aspect of tongue shaping in speech has been practically unexplored, with the exception of descriptions of sibilants such as |s| [3–5]. Recent speech research utilizing coronal ultrasound scans of the tongue, [6] has revealed that central grooving is also present on many vowels anteriorly, and especially posteriorly, on the tongue.

A comparison of posterior tongue grooving for speech and swallowing is of medical significance in the area of dysphagia therapy. Speech is a voluntary function, whereas only the initial oral stage of swallowing is considered to be under voluntary control. Posterior grooving of the tongue takes place as the bolus is being delivered into the pharynx and the involuntary pharyngeal phase of swallowing commences [7]. Persons who are unable effectively to form and channel a bolus with the tongue may experience uncontrolled premature entrance of the material into the pharynx, with the possibility of aspirating before the reflexive swallow occurs. In swallowing therapy, voluntary compensations are taught to a dysphagic patient [8, 9]. Speech function or imagery involving speech activity could be a useful aid in evoking appropriate tongue function for swallowing, if it were known which speech contexts most closely resembled tongue activity found for swallowing.

Materials and Methods

This study involved 7 normal subjects between the ages of 21 and 47 years. All were speakers of English. None reported or were observed to have any speech disorder or swallowing difficulty.

Instrumentation

Real-time ultrasound (US) images were produced with an Advanced Technologies Laboratories (Belleview, WA, USA) ultrasound unit and recorded on videotape. A 3 MHz mechanical sector scanner transducer was used, which had a focal depth of 7 cm and produced a scanning rate of 30 frames. An acoustic standoff (Kitecko, 3M Co.) was attached to the top of the transducer, distancing it from the mandible and permitting the

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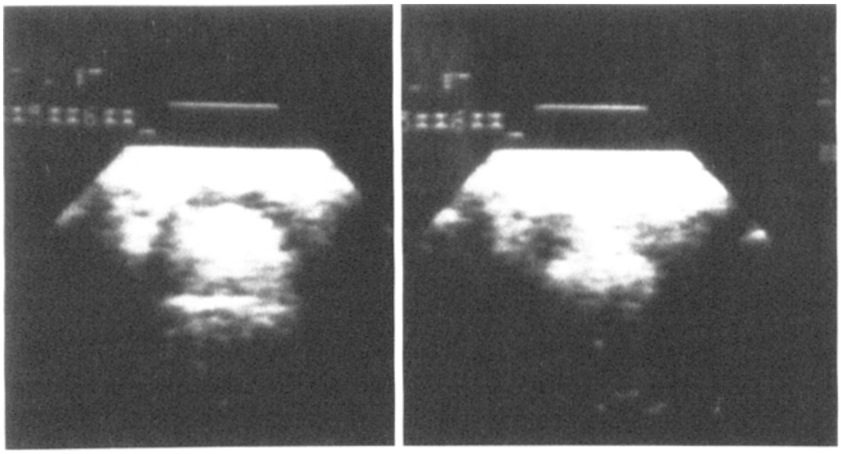

Fig. 1. Cross-sectional ultrasound sector scans of two stages in a dry swallow: tongue surface visible just prior to the reflexive swallow (*left*), and altered appearance of tongue musculature accompanied by disappearance of the tongue surface echo (*right*).

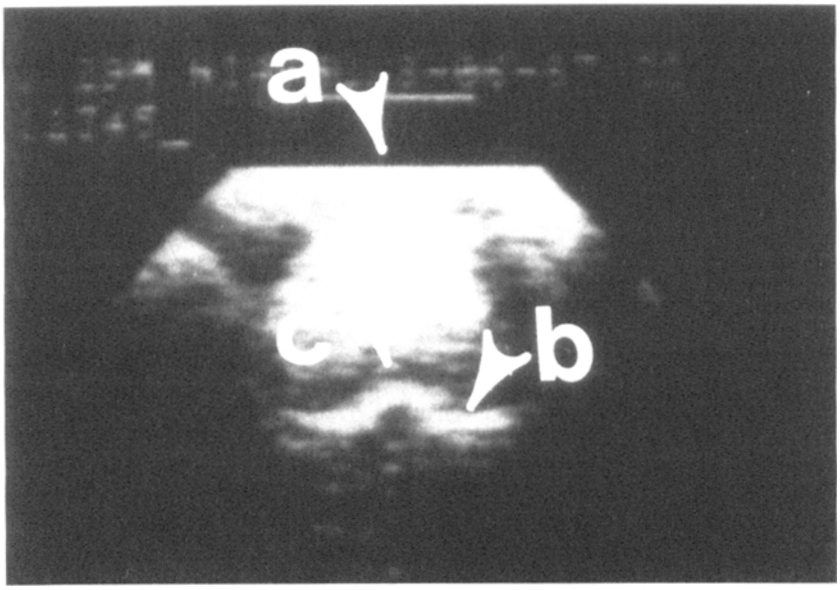

Fig. 2. Cross-sectional sector scan of the posterior tongue surface showing tongue groove. The image is inverted as it would appear on the scanner screen. Measurement points are (*a*) transducer face, (*b*) lateral tongue surface, and (*c*) midsagittal tongue surface.

entire tongue to be imaged. The standoff also permitted small natural jaw movements to occur without translating the motion to the transducer.

Speech was transduced by a cardioid microphone (Electro-voice, Inc) and recorded on the audio track of the video recorder. The microphone signal was also recorded simultaneously as a waveform display on the video image, along with a digital clock displaying time to 0.01 s.

Procedures

The subject was seated in a dental chair and the transducer was positioned under the jaw to scan in a cross sectional plane, 40 degrees posterior to the perpendicular of the inferior border of the mandible. Thus the base of the tongue was imaged in the velar region. A specially designed transducer holder stabilized the ultrasound transducer, in intimate submental contact, at a constant contact force. A head holder was then placed around the subject's head to brace it into position. A detailed description of the transducer holder and head holder has been published previously [6].

The sequence of tasks was as follows. The subject w asked to utter one of the following sustained vowels (i, I, ɛ, æ, ʌ, ɑ, o, U, u), then to say that vowel five times in t speech context (həpVpə). After the speech task for each vow the subject was given a measured 10 ml of water from a syrin and asked to swallow on command. Immediately afterwar a second "dry" swallow was requested. This sequence was us to provide some control over the amount of moisture in t mouth for the "dry" swallow. For each subject, analysis w done on sustained vowels plus two examples of each vow in context, and on five of the dry swallows.

Data Analysis

For analysis, the videotaped ultrasound data were review frame by frame until a frame of interest was identified. Fram of interest were determined as follows. The speech signal d played visually on the recorded image was used to determi the temporal domain of the sound being analyzed. When th was variability in tongue position within a vowel, the fra showing the most extreme grooving was chosen. Not all t data were of measurable quality: there were more unmeasurable data for males, with subject 7 being particularly problematic in this respect.

For analysis of dry swallows, tongue activity was scrutinized just after the command to swallow. The reflexive swallow can be recognized on a US cross-sectional sector scan because the longitudinal tongue and floor of mouth muscles suddenly change appearance, becoming more rounded (Fig. 1), and the echo from the tongue surface disappears. This changed image remains stable for a few hundred milliseconds and then reverts to the previous appearance. The several video frames just prior to the onset of this index of the reflexive swallow were reviewed, and the one showing the most extreme anterior inferior posturing of the midsagittal tongue groove was chosen for measurement.

Once a frame was identified for measurement, it was captured in digital form using an IBM-PC computer and Image Measure software. The image-enhancement capabilities of this software were used to provide optimal definition of the tongue surface. Distance measurements were then made directly on the digitized image displayed on the monitor, again using the Image Measure software (Fig. 2). One point (on the midline of the transducer face) was designated as "zero," and its pixel X and Y coordinates noted. The distance between the middle of the groove and the transducer face was then measured digitally for both the vowels and the swallows. Groove depth was also measured for both vowels and swallows. In cases of asymmetry, the side showing the greater difference between medial and lateral tongue surface position was measured. All of the measurements were normalized to the centimeter scale that appeared on the scans.

Results

Several features of tongue shape and position were examined to compare the speech and swallowing gestures. These features are (1) the depth of the midsagittal tongue groove, (2) the distance between the midline of the tongue and the US transducer, and (3) the timing relationship between the occurrence of maximal grooving and the subsequent change in appearance of the tongue muscles along with disappearance of the tongue surface echo.

The depth of the posterior tongue groove for swallowing varied individually, with female subjects showing more extreme grooving than males. Data for the individual subjects appear in Table 1. The average depth of tongue groove for swallowing was 7.7 mm. This compares to a range of mean tongue groove depths for vowels from 15.4 mm for |i| as in "see" to 2.2 mm for |a| as in "hot." The greatest similarity between mean groove depths for vowels and swallowing were for the vowels |æ| as in "cat" (8.9 mm) and |e| as in "plate" (9.9 mm).

The second feature of interest is the distance between the midgroove tongue surface and the transducer. Previous research on vowels has indicated that for a single subject at the scan angle

Table 1. Depth of tongue groove for swallow, based on 5 dry swallows per subject

Subject Gender	Mean (mm)	Range (mm)
1 F	8.0	2.9 10.1
2 F	13.6	6.1 22.9
3 F	9.2	8.0 11.0
4 F	8.2	4.0 12.0
5 M	5.2	4.0 6.0
6 M	2.0	1.0 4.0
7 M	6.2	3.0 8.0

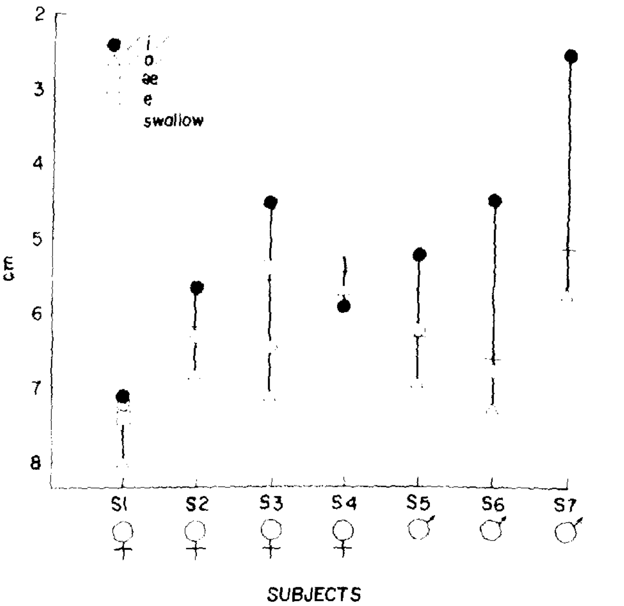

Fig. 3. Comparison of midsagittal tongue surface echo location in relation to the transducer face for swallow and selected vowels.

studied, the midline tongue is considerably closer to the transducer for |i| (3.1 cm) than for |a| (5.3 cm) [6]. The present data uphold that finding for 6 of the 7 subjects. In addition the data indicate that the tongue surface-to-transducer distances seen in swallowing fall between |i| and |a| (Fig. 3). The vowel |æ| was uttered with a tongue surface position most similar to swallowing by the majority of these subjects. For subjects 1 and 3, the vowel |e| was most similar to the tongue surface position for swallowing, so data for that vowel are also provided.

The third feature studied with respect to swallowing was the timing relationship between the video frame showing maximal tongue grooving and the onset of the rapid change in appearance of underlying tongue muscles. This time was calculated from the number of video frames (at 30 frames/s) separating the two events. The average time between these events was 305 ms.

Discussion

The displacement of the midline tongue and the depth of the tongue groove are comparable in swallowing to the vowels |e| and |æ| rather than to the vowel |i|, which has the most extreme grooving in speech. To utter an |i|, the entire base of the tongue is displaced anteriorly [11], widening the pharynx and opening the laryngeal vestibule. The posture for the vowel |i| is thus not conducive to facilitating rapid airway protection during the pharyngeal phase of swallow when the larynx is pulled forward and under the base of the tongue. The vowel |æ|, on the other hand, has a greater degree of pharyngeal constriction, yet still incorporates posterior tongue grooving as is needed for central containment and channeling of the bolus.

We do not have independent validating evidence to tell when in the sequence of swallowing our tongue grooving measurements were taken, and cross-sectional real-time ultrasound scans do not give as complete a picture as real-time sagittal scans, but we suggest the following interpretation. In deglutition the maximum posterior tongue grooving occurred an average of 305 ms before a rapid change in appearance of longitudinal tongue muscles in the cross-sectional US scans, along with disappearance of the tongue echo. One of the most rapid events in swallowing is the anterior movement of the hyoid bone, which pulls the larynx under the base of the tongue as the bolus passes through the laryngopharynx and into the esophagus. In normal swallows, the rapid forward movement of the hyoid ends an average of 267 ms after the barium bolus moves over the base of the tongue and begins its vertical descent into the pharynx [12]. The change in appearance of the longitudinal tongue and floor of mouth muscle is consistent with strong contraction of muscles attaching on the hyoid bone. At approximately the same time as the muscular appearance in the image changed, the echo from the tongue surface disappears. The disappearance of the air/tongue interface has also been described for sagittal ultrasonic scans of swallowing. This occurs as the tongue and palate make direct contact during the stripping action and as the hyoid moves forward and upward [13]. Thus we are suggesting that the maximum grooving of the posterior tongue occurred an average of 305 ms prior to when the minimal bolus for a dry swallow was propelled into the pharnyx and the larynx was pulled under the base of the tongue.

The possibility of using real-time ultrasoun scanning for biofeedback in speech training ha been noted [14]. It appears that ultrasound scan ning would also hold promise for biofeedback i certain aspects of swallowing therapy, notably th tongue conformations for oral formation an channeling of the bolus. The neurologic organiza tion for normal speech and swallowing is no dout quite different, even for the voluntary oral stag of swallowing. But in the beginning stages of dy phagia therapy for poor tongue control, approx mations to desired function may be sought usin whatever voluntary capabilities are present. Speec therapy may likewise begin training with sustaine sounds, even though the ultimate goal is contextu speech, which represents a different task. Ultra sound is an imaging technique that can be use safely for long-term and repeated assessment, an thus is also well suited to evaluating the succe of training.

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