Tongue shape dynamics in swallowing

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Introduction

During liquid swallowing, the tongue controls the liquid in a bolus in the oral cavity, changing shape, position and constriction to transport it into down into the pharynx. There are various methods for tongue movement measurement during swallowing: videofluoroscopy [Dodds et al (1990)], magnetic resonance imaging [Hartl et al (2003)] and ultrasound [Shawker et al (1983)]. Real-time ultrasound is simple, repeatable, and its dynamic soft tissue imaging may make it superior to others for swallowing research, and so we aim to test this hypothesis and measure certain spatial and dynamic aspects of the swallow in a consistent manner across participants.

Method

Eleven healthy adults (2 male and 9 female) between the ages of 19 and 35 participated in the study. Both thickened and thin liquids were used, and liquid bolus volumes of 10 and 25ml at room temperature were administrated to the subject using a cup. Three swallow tokens for each of the four bolus volume/viscosity were sampled, for a total of 12 swallows per subject.

The tongue surface was traced from the time at which the tongue moved up toward the palate at the start of swallowing, to the time when the entire tongue was in contact with the palate.

The distance (in mm) was calculated using AAA software, measuring along each radial fan line from the point where the tongue surface spline intersected the fan line to the point where the hard plate intersected the fan line in each individual plot. Each splines was calculated on sequential video frames while the middle of the tongue formed a concavity in preparatory positon. The depression distance was defined the longest distance from hard plate to tongue surface.

Results part 1

Qualitatively, there were differences between individual participants, and we defined quantitatively Measureable and Unmeasurable types. Figure 1 shows the most common type: Measureable, in which we could find a clear bolus depression in a cupped tongue surface. In 10ml thin liquids, we were able to find and measure the depression distance for all participants. In 10ml thickened liquids participants, we were not able to measure the depression distance for seven participants. Four participants were Unmeasurable in 25ml thickened liquids, and in 25ml thin liquids, two participants were Unmeasurable and one participant had unclear splines.

Results part 2

To make best use of the data, 10ml thin, 25ml thickened and 25ml thin (all Measurable types) were compared. Statistical comparison (ANOVA was possible therefore from 7 participants). The average maximum radial depression distance from palate to tongue surface was 20.9±4.3mm for 10ml thin liquid swallow compered 24.6±3.3mm for 25ml thin liquid swallow ($p < 0.001$). The average depression distance was 22.3±4.7mm for 25ml thickened liquid swallow compared with 25ml thin liquid swallow ($p < 0.01$).

Conclusion

We conclude that it is possible to use ultrasound tongue imaging to capture spatial aspects of swallowing. We will also discuss and exemplify dynamics of tongue constriction and the movement of the constriction from anterior to posterior.

References

Dodds W.J., Stewart E.T., Logemann J.A .Physiology and radiology of the normal oral and pharyngeal phases of swallowing, American Journal of Roentgenology 154(5):953-63,1990

Hartl D.M., Albiter M., Kolb .F et al.Morphologic parameters of normal swallowing events using single-shot fast spin echo dynamic MRI. Dysphagia,18(4): 255–62,2003

Shawker T.H., Sonies B, Stone M et al: Real-time ultrasound visualization of tongue movement during swallowing. J Clin Ultrasound, 11(9): 485–90,1983

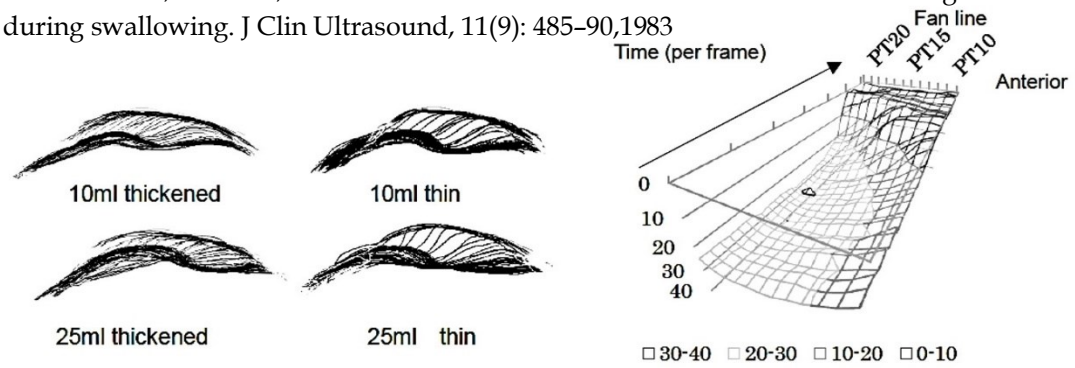

Figure 1. 22 year old female. Overlaid tongue curve splines (left) for four bolus types, and 3D time series (right) for the same 25ml thin bolus data, showing radial distance from tongue to palate along fan-shaped grid radii. The anterior constriction forms first at fanline PT10, then the contact spreads back across the palate to PT20. The anterior parts of the vocal tract are to the right in each image.

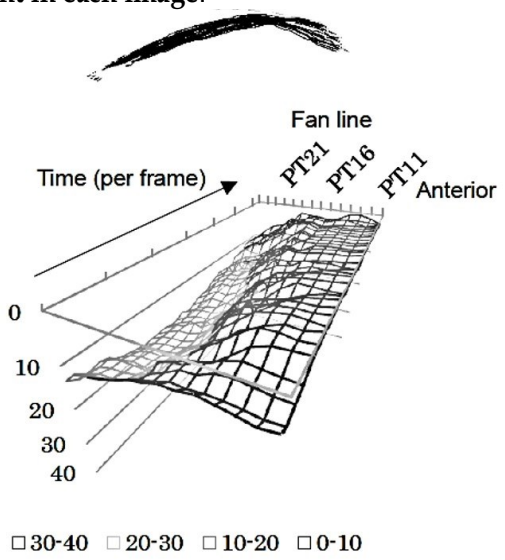

Figure 2

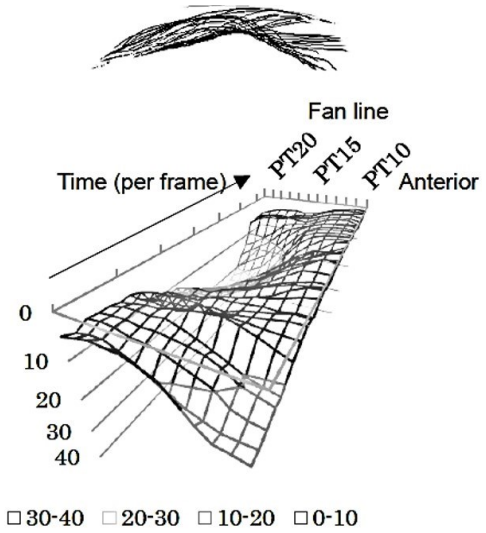

Figure 3

Figures 2 & 3 illustrate the Unmeasurable types. Figure 2 is a 19 year old female in which the tongue's surface didn't make a travelling concavity and the detected movement was only very slight. Figure 3 shows data from a 24 year old female with an anterior concavity at the start and a dorsal concavity later (just before, at the end of the transport, the near-complete closure), but, in between these times, the front / middle of the tongue didn't form the clear concavity travelling in a posterior direction as might be expected. This may be because, unusually, she held the dorsal part of her tongue near to or touching the palate at the start of the process.