Quantification of tongue movement in discrete and continuous swallowing using Ultrasound Evaluation of Swallowing (USES)

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Introduction

Tongue movement plays a crucial role in the oral preparatory and oral stages of swallowing, contributing to bolus containment and bolus propulsion. However, quantifying tongue contour in swallowing presents methodological challenges, particularly for clinical translation. Using kinematic and anatomical evidence, Wrench (2024) proposed a compartmental tongue model consisting of five neuromuscular compartments (NMCs) to explain the subtle and diverse tongue shapes in speech. Specifically, five sectors of the tongue body, labelled GG1 (tongue root) to GG 5 (anterior tongue body), work in synergy to shape and position the tongue.
This study applies the compartmental tongue theory to the swallowing and proposes a novel methodological approach for analysing swallowing tongue movement in Ultrasound Evaluation of Swallowing (USES).

Methods

Single and continuous water swallow data were obtained from five healthy adults using a portable pocket-sized Micro ultrasound system in standard B-mode. A 60mm convex probe was fitted on the UltraFit headset to maintain a stable midsagittal view.

A DeepLabCut (DLC) neural net was trained to estimate the tongue contour for hundreds of ultrasound frames in seconds. Due to distinct muscular control, tongue tip and blade were excluded from this analysis. The distance between the short tendon of the mandible and the tongue body contour was measured at five evenly spaced points (GG1 to GG5) at four manually annotated timepoints:

(1) Neutral tongue position before bolus entry

(2) End of bolus hold before tongue tip raising

(3) Initial tongue tip-palate contact

(4) Hyoid at maximal anterior position

Results

Consistent movement patterns were observed during single swallows. Anterior bolus hold was achieved through shortening of GG 5 to create space anteriorly, alongside lengthening of GG1 to GG3, which elevated the tongue dorsum and retracted the tongue root. Tongue tip and palate contact at bolus propulsion onset involved GG5 extension and GG3 shortening, corresponding to posterior tongue lowering. GG1 and GG2 shortening aligned with peak hyoid advancement, during which a sequential contraction and extension of GG5, GG4 and GG3 facilitated the posterior delivery of the bolus.

Continuous swallows showed a similar overall pattern, but demonstrated variability in bolus hold strategies. Two main patterns were identified: (1) tongue tip lowering and GG5 shortening (as in single swallows), and (2) tongue tip elevation with anterior bolus hold achieved via GG4 and GG5 shortening to a smaller extent. The raised position of GG3 remained consistent across both strategies. These patterns appeared to be linked to bolus volume, with a mixed use of both patterns noted in some participants.

Discussion/Conclusion

The study presents a novel method for quantifying tongue movement during swallowing, based on a compartmental anatomical framework. The integration of ultrasound imaging and machine learning enables objective analysis of sequential tongue movements across defined anatomical regions. This approach enhances our understanding of the oral preparatory and oral stages and holds promise for clinical comparisons of typical and atypical swallowing patterns. Future work extending this model to disordered populations will further validate its clinical utility.

Reference:

Wrench, A. A. (2024). The Compartmental Tongue. *Journal of Speech, Language, and Hearing Research*, *67* (10s), 3887–3913. pp. https://doi.org/10.1044/2024_jslhr-23-00125