High-Speed Laryngoscopic Evaluation of the Effect of Glottal Parameter Variation on Aryepiglottic Trilling

Scott R. Moisik, John H. Esling, and Lise Crevier-Buchman

Aryepiglottic trilling is at once an extreme example of a pharyngeal articulation and a source generator for the vocal tract. This trill may even be interpreted as a *pharyngeal* source. Its precise nature has not yet been carefully examined, primarily due to its misidentification as a dysphonic or pathological function of the larynx. Robust evidence, however, has mounted (Edmondson et al. 2007) that attests its role in the realization of pharyngeal contrasts in numerous languages ranging from Africa, Western China, Southeast Asia, and the Pacific Northwest (Edmondson & Esling 2006). Furthermore, it is a broadly employed phonatory state for numerous musical styles, particularly the Rhythm and Blues singers of the 1900's such as Louis Armstrong, Koko Taylor, and Louis Prima, and also is frequently heard in more modern singing such as the vocal stylings of artists like Tom Waits. Beyond this, aryepiglottic trilling is frequently heard as an exponent of various emotional states.

Our aim is to elaborate upon an existing biomechanical model of the aryepiglottic folds that simulates their function under highly simplified aerodynamic and physiological conditions. Particularly, the current model is only capable of realistically depicting fold movement when there is a glottal source (Moisik & Esling 2008; Moisik 2008). The aryepiglottic folds, however, do not require vocal fold vibration to function, as it is fully possible to engage them in trilling with the glottis open. Elaboration of the simulation cannot be achieved without first learning more about the function of the aryepiglottic folds during conditions other than vocal fold vibration at the common frequency of 100 Hz (for males). What is required is identification of trilling parameters varying in glottal parameter settings, particularly voiceless aryepiglottic trill and trilling at various glottal frequencies both above and below the standard level.

Our research involved the acquisition of several high-speed laryngoscopic videos of aryepiglottic trills, manipulating the parameters described above. We recorded seven sequences of a trained phonetician performing the trills. Voiced and voiceless trills were recorded. The voiced trill was produced with a baseline glottal pulse frequency of 100 Hz and 200 Hz. Voiceless trilling was produced to emulate the voiced postures at the same frequencies. Modification to airflow was also made by manipulating the medial laryngeal outlet channel; the settings explored could be described as loose, moderate and tight overall stricture. The videos were then analyzed using two simple automated image analysis techniques: aperture area measurement and kymography (see Švec 2008). Evaluation of vibrational modes from the image analysis, in addition to visual inspection of the videos themselves, reveals tremendous variability in oscillatory patterns of the aryepiglottic folds within a single individual. Under conditions of vocal fold vibration, bilateral properties of movement are frequently asymmetric while overall vibration is quasiperiodic or aperiodic; pulse phases are uneven between the two folds as well. The folds also exhibit interaction with the surface of the epiglottis: there is evidence of mucosal resistance to the aryepiglottic pulse if the fold comes into direct contact with the epiglottis. Where cuneiform positioning results in a more patent aryepiglottic aperture, pulse characteristics are complex and may contain more rapid but minor fluctuations in the tissue comprising the aperture. With increased stricture the folds show resistance to oscillation, and the apertures diminish in area considerably: at extreme levels of stricture no aperture formation is evident, but the entire laryngeal collar can be seen vibrating. Aryepiglottic trilling showed similar pulse patterns at both levels of glottal frequency (100 & 200 Hz). The voiceless trills are characterized by far more intense and vigorous movement of the aryepiglottic folds; at times the cuneiform tubercle itself vibrated sympathetically with the fold, indicative of its highly elastic properties (see Figure 1). Increasing frequency showed concomitant tightening of the sphincter with surface waves travelling up through both aryepiglottic channels; like the voiced variant, the aryepiglottic fold edges vibrated similarly to the trills at lower frequencies.

While vocal fold vibration is much more constrained in nature, aryepiglottic vibration is comparable to that of a flag or sail flapping under intense wind. This has important implications for the perception of trills: given the variability in pulse period and the possibility for multiple sources, trill perception must rely on its aperiodic nature as one cue. Spectral characteristics are also likely to be another robust cue. Articulatorily, the trill shows considerable variation as well: where airflow is adjustable by modifying the central channel, the classification is a whispery harsh voice. Tightening the aryepiglottic sphincter yields a much more resonant, less noisy variant. Future work will integrate these findings into a biomechanical model of the aryepiglottic folds; the data serve as target trilling patterns and values for future simulations using the model.

Figure 1: Frames 422 to 434 (only even frames) illustrating voiceless aryepiglottic trill emulating the voiced posture at 100 Hz. This sequence represents 24.04 ms. There is a bilateral phase difference in the aryepiglottic pulsing. Note also the extreme displacement of the left cuneiform tubercle.

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Affiliations and Contact Information:

Scott R. Moisik and John H. Esling (srmoisik@uvic.ca; esling@uvic.ca)
Department of Linguistics, University of Victoria, Victoria, BC, Canada

Lise Crevier-Buchman (lise.buchman@numericable.fr)
Laboratoire de Phonétique et Phonologie, UMR 7018, CNRS/Sorbonne-Nouvelle,Paris, France