Contrasting Chest and Falsetto-like Vibration Patterns of the Vocal Folds

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Abstract: Using excised larynxes, a hemilarynx methodology was used in order to view vocal fold vibrations from a medial aspect. This was accomplished by removing one fold, inserting a glass plate at the glottal mid-line, and mounting the remaining fold against the glass plate. A high-speed stereoscopic imaging system was used to perform the 3D tracking of small markers (microsutures) placed on the folds. Chest and falsetto-like vibration patterns were imaged and quantified.

INTRODUCTION

Videostroboscopy is undoubtedly one of the most common tools for viewing laryngeal vibration. While it is possible to make dynamic quantitative estimates of glottal area using this technique, the 2D images recorded on video do not contain enough information to reconstruct the 3D vibration patterns of the folds. In particular, the superior view prohibits direct measurement of any vertical vibrations, and during glottal closure, the medial and inferior surfaces of the folds are completely hidden from view. The excised canine studies of Baer (1975) are one of the few quantitative studies of vocal fold vibration, in which individual trajectories of fleshpoints were tracked throughout the entire glottal cycle. Building on the studies of Baer (1975), the present study utilizes a stereoscopic high-speed video system to track individual vocal fold fleshpoints during the phonation of excised larynxes. This technique not only enables the quantification of periodic vibrations, but also transitions between vocal registers and other aperiodic phenomena. This paper will focus on the stereoscopic, high-speed methodology which enables the quantitative observations, as well as the analytic methods utilized in deriving the 3D coordinates from the digital images.

METHODS

Jiang and Titze (1993) demonstrated the feasibility of using a hemilarynx setup as a substitute for a full larynx in experimental situations. While the set-up assumes left-right symmetry of the folds (i.e., that they collide at a common midline), it allows direct observation of the medial surface of the vocal folds. Furthermore, if one places micro-suture markers on the folds and views the vibrations from two slightly different angles, 3D trajectories of vocal fold fleshpoints may be quantified. Distinct vibration patterns of the folds may then be contrasted. Through use of a high-speed video system, both regular and irregular vibrations may be quantified.

![Figure 1](image-url)  
(a) a hemilarynx mounted against a glass plate, and stereoscopically viewed with a high-speed video system through a glass prism. (b) microsutures (represented by x’s) are placed on the upper medial surface of a coronal plane of the vocal folds.

One larynx from a 19 kg canine was used in this experiment. The animal was sacrificed for cardiac research at the University of Iowa Hospitals and Clinics, but the larynx was made available to us post-mortem. The larynx was initially dissected removing tissue superior to the vocal folds. The hemilarynx was developed by vertically splitting the larynx at the midline, and removing a vocal fold along with much of the ipsilateral thyroid and cricoid cartilages. The result appears to be a full larynx with an upper quadrant removed revealing the medial surface of the remaining vocal fold from a mid-sagittal view. Six 9-0 black-nylon micro-sutures were placed in a vertical line on the medial surface of the vocal fold situated at the midportion of the membranous fold. The hemilarynx was mounted against a glass plate followed by a prism to allow stereoscopic imaging of the sutures (Figure 1). Warm humified air was introduced through
the trachea to vibrate the vocal folds (Berry et al., 1996). A Kodak Ektapro 4540 was used to image the vocal fold vibrations. The recording rate was 4500 frames per second, each frame consisting of 256 x 256 pixels with 256 levels of gray scale. Up to 3072 digital frames could be stored in the system memory. With an ISO rating of 3000, imaging of the high-speed recordings was possible with a 250 Watt halogen light source (which was typically shuttered to further lower the light intensity).

![Image](a)

**Figure 2.** (a) A trajectory of one of the sutures, as shown by the elliptical trace. By upsampling the image, the center of the suture, as well as the ties are clearly visible. (b) A schematic of the reticle with 0.05 inch squares used to establish the calibration grid.

In order to calibrate physical coordinates from the image coordinates, the larynx was removed from the glass plate after all the imaging was completed. Held in place with a 3D micrometer, a low-reflection chrome contact reticle was placed against the glass plate, centered on the position where the sutures had been located. The reticle contained a grid of 0.05" squares, as shown in Figure 2a. The reticle was imaged, and then displaced 1 mm perpendicularly from the glass plate using the 3D micrometer, and then imaged again. The process was repeated for 2 and 3 mm, as well. Thus, a 3D calibration grid was established to perform a mapping from the image coordinates to physical coordinates. Such a mapping was performed using the Direct Linear Transformation (Abdel-Aziz and Karara, 1971; Shapiro, 1978). A correlation method was used to track the sutures of in both images. A sample of an extracted path from one of the sutures in one of the images is shown in Fig. 2b. The path is elliptical in nature, in agreement with previous results reported by Baer (1975).

**RESULTS**

Video animations of the vibration patterns will be demonstrated at the meeting, as well as quantitative comparisons of both chest and falsetto-like vibration patterns.

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**REFERENCES**


