HUMAN AIRFLOW VELOCITY DISTRIBUTION CHANGES FROM THE GLOTTIS THROUGH PHARYNX DURING PHONATION
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Abstract
Objectives: Human voices originate from the vibration of vocal folds in the larynx. In most previous studies on voice generation, a planar sound source was assumed for a laryngeal sound source and the effects of airflow in a larynx were neglected. However, no direct in vivo measurement of human glottal velocity has been reported. Therefore, detailed study of this airflow is necessary to elucidate mechanisms of human phonation.

Methods: In the present study, airflow just above the glottis was experimentally analyzed to clarify the phonation mechanism and seek better modeling of vocal folds. This experiment focused on direct measurement of the airflow velocity by means of a tiny probe and simultaneous observation of vocal fold movement by means of a high-speed digital camera.

Results: Experimental results show that the velocity of the glottal airflow is very high at the front of the glottis as a pulsatile jet and includes the high frequency fluctuation as a turbulent flow. Glottal airflow gradually decreases above the glottis and fade away in the pharynx.

Conclusions: The airflow velocity in the larynx has high frequency components. This results provide crucial information to create better simulation models of the phonation mechanism.

Introduction
The mechanical features and dynamics of the exit jet flow at the surface of the vocal folds are also essential. The exit jet flow may contain a high frequency harmonic component. In this study, we demonstrated the realistic direct measurement of glottal velocity just above the glottis in humans. A minute and flexible hot-wire probe inserted into a flexible transnasal endoscope. Detailed measurements of the velocity gradient in the anterior-posterior centerline velocity difference were observed.

Methods and Materials
The high-speed camera system was a FASTCAM-MAX (Photron). The images and signal from the anemometry were captured instantaneously in the camera processor memory. Glottal velocity was measured directly with a constant temperature anemometer (CTA), KANOMAX MODEL1011. Two separate flexible transnasal endoscopes were inserted in parallel from both sides of the nose. We used three light sources, each with a 300W Xenon lamp. The fiberoscopic examination was performed transnasally. The tip of the hot-wire probe was placed just above the glottis. The airflow velocity was recorded synchronously with the high-speed image (Figure 1). The subject was asked to produce steady phonation within the modal register and in a comfortable manner. The position of the probe-tip was moved anterior to posterior over the midline, and then elevated from the glottis.

Results
Figure 2a shows the glottal velocity just above the glottis. Figure 2b shows the glottal velocity fluctuation that the data was low pass filtered under 10 kHz. This figure indicates glottal velocity may contain high frequency components. Figure 3 shows the airflow velocity changes anterior to posterior in the midline. Applying root mean square processing to airflow velocity calculated among 10 phonation cycles. The strongest airflow velocity was found at the anterior midline of the vocal folds. Airflow velocity demonstrated proportionally lower from anterior to posterior commissure.

Next, the probe was elevated vertically from the glottis. Figure 4 shows the airflow velocity distributions at the different vertical distance from the glottis. The airflow velocity was strongest above the glottis and found uncertain apart 20mm from the glottis.

Discussion
We present a realistic evaluation of glottal velocity just above the glottis in human subjects. These measurements showed that glottal velocity changed in horizontally different position and maximum velocity achieved near anterior commissure. Human glottal velocity may consist of high frequency components, and may include vortices around the vocal fold vibration. The glottal velocity was highest just above the glottis and decreased apart from the glottis. The airflow was uncertain separated higher than 20mm.

Conclusions
Since the glottal area narrows, glottal velocity speeds up. The strongest glottal jet velocity was found at the anterior midline of the vocal folds. At the posterior shift of the midline, airflow velocity demonstrated lower than anterior airflow velocity.

References

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