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Experimental simulation of unilateral paralysis of human vocal folds

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Unilateral paralysis of the superior laryngeal nerve affecting the cricothyroid muscle produces an imbalance in the longitudinal tension of the vocal folds during phonation. Such an asymmetry causes changes in the vibratory pattern of the vocal folds and in the resulting voice quality, e.g. hoarseness, voice breaks, limited pitch and loudness range. This problem was studied by means of a physical model of the human voice production.

The model consists of vocal fold replica made of silicon and a plexiglass tube representing the vocal tract configured for [u:] vowel. For the measurement setup see [2]. A two-layer water-filled silicone vocal fold replica [2] was excited by the airflow coming from a compressor through a regulating valve into the float flow meter, based on which the control flow rate was manually set to 0.25 l/s. The air entered the model of subglottal spaces consisting of a simplified model of lungs and trachea. Thereafter, the air flew into the part where the vocal folds were installed. The hydrostatic pressure inside the vocal fold model was regulated by a syringe to pre-set the fundamental frequency of phonation to a fixed value 110 Hz. The mean subglottal and oral pressures were measured by NXP (Freescale) MPXV5010GC6U integrated pressure semiconductor sensors mounted in the walls of the trachea and the oral cavity. The fluctuations of the subglottal and oral pressures were measured by a B&K 4138 miniature microphone (range 6.5 Hz–140 kHz) and by a special B&K 4182 microphone probe (range 1 Hz–20 kHz), respectively. Vocal fold vibrations were recorded by the high-speed camera (NanoSense MkIII) positioned at a 90 degree bend of the trachea model where a glass window was installed; this enabled the viewing of the vocal fold vibration from the subglottal side.

All the pressure signals were synchronously sampled and recorded using the measurement system B&K Pulse 3560 C controlled by a personal computer equipped by the SW PULSE LabShop Version 10. The sampling frequency of the signals was 16.4 kHz, and 1000 frames were synchronously recorded by the high-speed camera with the rate of 3000 frames/s.

Fig. 1 shows the videokymogram of the vibratory pattern of the vocal folds constructed from the perpendicular cross line at the position of the maximal glottal width amplitude. The black pixels represent the glottal width $GW(t)$ at the individual time instants of video recording. This vibration pattern resembles pathological asymmetric vibration patterns observed in vivo in patients with unilateral vocal fold paralysis [4, 1]. Notice the period irregularities on both the vocal folds which are typical for rough or diplophonic voices [5]. Also, notice the reduced amplitude of vibration of the left (lower) vocal fold, which suggests a mass imbalance rather than a stiffness imbalance of the vocal folds or extremely tensed left vocal fold, see [3].

Fig. 2 demonstrates time records of the following measured signals: oral pressure $P_{oral}(t)$ measured in the mouth cavity of the vocal tract model, glottal area $GA(t)$ and subglottal pressure $P_{sub}(t)$ measured just below the vocal folds. The beats-like vibration pattern of all the signals is similar to that seen in the videokymogram.

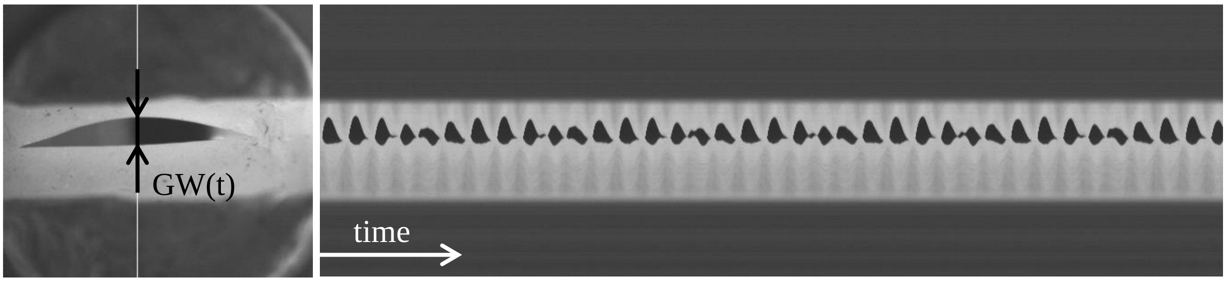

Fig. 1. Position of the cross line for videokymogram construction (left), videokymogram of vibrating paralysed vocal folds model (right)

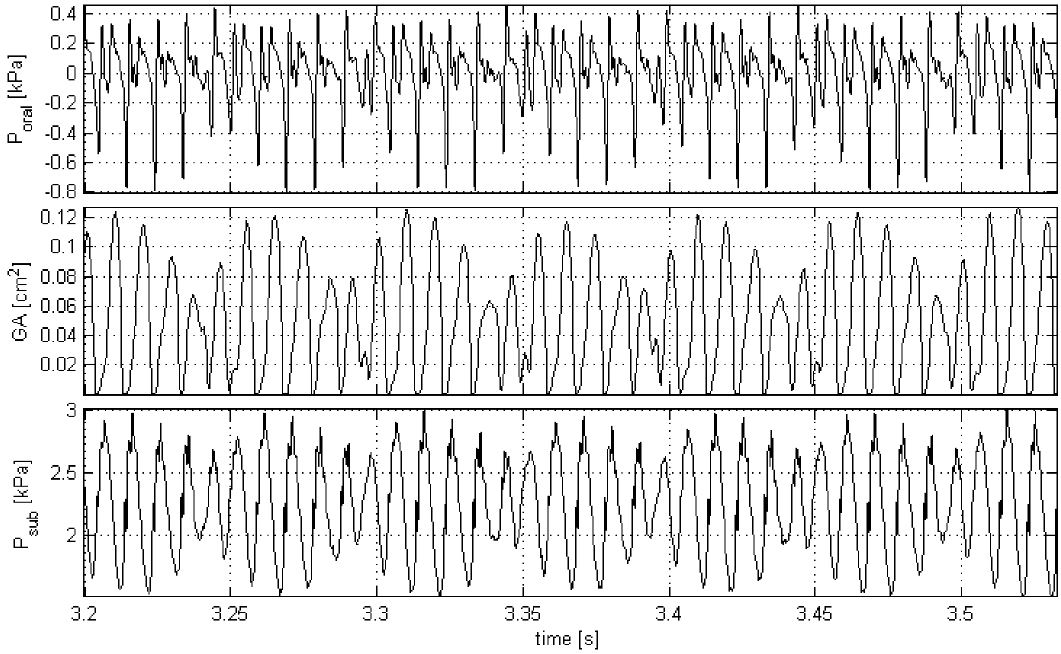

Fig. 2. Waveforms of vibrating paralysed vocal folds model: oral pressure (top), glottal area, subglottal pressure (bottom)

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References

[1] Eysholdt, U., Rosanowski, F., Hoppe, U., Vocal fold vibration irregularities caused by different types of laryngeal asymmetry, European archives of otorhinolaryngology 260 (2003) 412-417.

[2] Horáček, J., et al., Experimental modelling of phonation using artificial models of human vocal folds and vocal tracts, Proceedings of the 23rd International Conference Engineering Mechanics, Svratka, 2017, pp. 382-385.

[3] Isshiki, N., et al., Clinical significance of asymmetrical vocal cord tension, The Annals of otology, rhinology and laryngology 86 (1977) 58-66.

[4] Sram, F., Schutte, H.K., Svec, J.G., Clinical applications of videokymography, Proceedings of the 16th World Congress of Otorhinolaryngology Head and Neck Surgery, Sydney, 1997, pp. 1681-1684.

[5] Svec, J.G., Sram, F., Schutte, H.K., Videokymography in voice disorders: what to look for?, The Annals of otology, rhinology and laryngology 116 (2007) 172-180.