The First Application of the Two-Dimensional Scanning Videokymography in Excised Canine Larynx Model

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Summary: Objective. Evaluation of the vibratory pattern of vocal folds is of paramount importance to diagnose vocal fold disorders. Currently, laryngeal videokymography (VKG) and digital kymography from high-speed videolaryngoscopy are the available techniques for studying aperiodic vibrations of vocal folds. But VKG has the fundamental limitation that only linear portion of the vocal fold mucosa can be visualized. Digital kymography has the disadvantages of no immediate feedback during examination, considerable waiting time before kymographic visualization, recoding duration limited to seconds, and extreme demands on storage space. We developed a new system—two-dimensional (2D) scanning VKG—for evaluation of the vibratory pattern of vocal folds, and the method provided a possible alternative with its advantages and disadvantages. Thus, we aimed to evaluate the feasibility of the new device for the vocal fold vibration in excised canine larynx model.

Methods. The vibrating pattern for vocal folds was evaluated using high-speed videolaryngoscopic and 2D scanning videokymographic system in the excised canine larynx model.

Results. The images of canine vocal folds were captured with high-speed videolaryngoscopic system and converted to the kymographic images using the software. The kymographic image acquired by 2D scanning VKG was comparable with multi-line digital kymography at multiple locations.

Conclusions. The vocal fold vibration could be evaluated in the excised canine larynx model using 2D scanning VKG. And this new device is expected to be a promising tool to evaluate the vocal fold vibration for clinical practice and voice research.

Key Words: Videokymography–Vocal fold–Vibration–Canine larynx–High-speed video system.

INTRODUCTION

Examination of the vibratory movement of vocal fold mucosa is important to understand the mechanism of voice production and to diagnose various vocal fold disorders. Laryngeal videostroboscopy is widely used to show "illusory" slow motion images of the vibrating vocal folds. However, it can usually obtain a clear image when vocal fold vibrations are periodic with stable phonation frequency.[1] Currently, laryngeal videokymography (VKG) and high-speed videolaryngoscopic system are the only available techniques for directly studying aperiodic vibrations of vocal folds.[2]

Laryngeal VKG was developed to enable kymographic image encoded as a standard video signal[3] and can reveal the vocal fold kymography directly on a standard video monitor.[4] But VKG has the fundamental limitation that only linear portion of the vocal fold mucosa can be visualized. For the evaluation of the motion of the whole vocal fold vibration, laryngeal high-speed imaging system was introduced.[5] Digital kymography is extracted from the images obtained in laryngeal high-speed imaging system and show the real vibratory image of vocal folds mucosa.[6,7] But it has the disadvantages of no immediate feedback during examination, considerable waiting time before kymographic visualization, recoding duration limited to seconds, and extreme demands on storage space.[8]

To overcome these limitations of the previous methods, we developed a new videokymographic system for two-dimensional (2D) analysis of the whole vocal folds.[9] In this article, we report the first application of 2D scanning VKG for the vocal fold vibration in the excised canine larynx model.

MATERIALS AND METHODS

Excised canine larynx model

A male dog weighing 8 kg was used in this study. The dog was sacrificed for this study, and the larynx was eviscerated from the fourth tracheal ring to the hyoid bone. Supraglottal structures such as epiglottis, false vocal folds, and aryepiglottic folds were removed. Interarytenoid approximation was performed to medialize the vocal folds for the excised larynx. The prepared excised larynx was fixed in the lung apparatus designed for the canine model, and an endotracheal tube was used to seal off the trachea and to deliver airflow to the glottis. The endoscope could be moved to and pro for the appropriate distance from the canine larynx (Figure 1).

High-speed videolaryngoscopic system and digital kymography

Laryngeal color high-speed video system (KayPENTAX, Model 9710, Montvale, NJ, USA) with a rigid endoscope (Storz, 10 mm, 0°Laryngoscope, 8701AG, Germany) was used to

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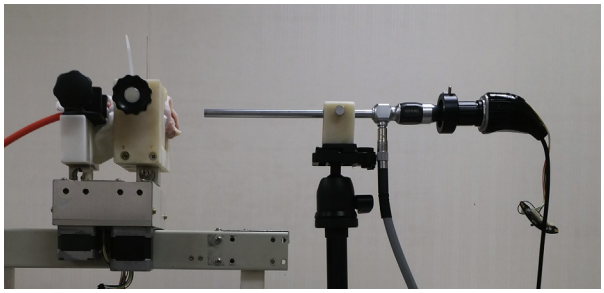

FIGURE 1. The setting of two-dimensional (2D) scanning kymography for the excised canine larynx. The prepared excised larynx was fixed in the lung apparatus designed for the canine model, and an endotracheal tube was used to seal off the trachea and to deliver airflow to the glottis. The endoscope could be mobilized to and pro for the appropriate distance from the canine larynx. Full HD CMOS (complementary metal oxide semiconductor) image sensor (1920 × 1080 pixels) and rolling shutter camera were implemented to the new device. A rigid endoscope (Storz, 10 mm, 0°Laryngoscope) were assembled with the new device to the system.

capture the vocal fold mucosa of the excised canine larynx at 2000 frames per second. The obtained images were converted to the kymographic image (digital kymography) using Kay's image processing software (*KIPS*, KayPENTAX, Model 9181).

Two-dimensional scanning VKG

Two-dimensional videokymographic system was manufactured in cooperation with U-medical Co. LTD (Busan, Korea). Full HD CMOS (complementary metal oxide semiconductor) image sensor (1920 × 1080 pixels) and rolling shutter camera were implemented to the new device. A rigid endoscope (Storz, 10 mm, 0°Laryngoscope) and A 300-W xenon light source (Storz, NOVA 300) were assembled with the new device to the system (Figure 1). The system was used to capture the entire vocal fold of the excised canine larynx, and the video was recorded at 30 frames per second. The resolution of the final 2D VKG images was 1920 × 1080 pixels, and the exposition time of a single line displayed in the image (1920 × 1080 pixels) was 1/32 400 second because the scanning time for one frame with a rolling shutter camera is 1/30 second.

RESULTS

High-speed videolaryngoscopic imaging and digital kymography in the excised canine larynx model

The vocal folds vibration of the excised canine larynx was captured with high-speed videolaryngoscopic system at 2000 frames per second. The fundamental frequency measured 387 Hz with the microphone. The obtained video was processed using Kay's image processing software, and digital kymography was extracted in the four levels of the vocal folds (Figure 2).

Two-dimensional VKG imaging in the excised canine larynx model

The vibrating images of the canine vocal folds were captured with 2D scanning VKG system (Figure 3). The rolling shutter

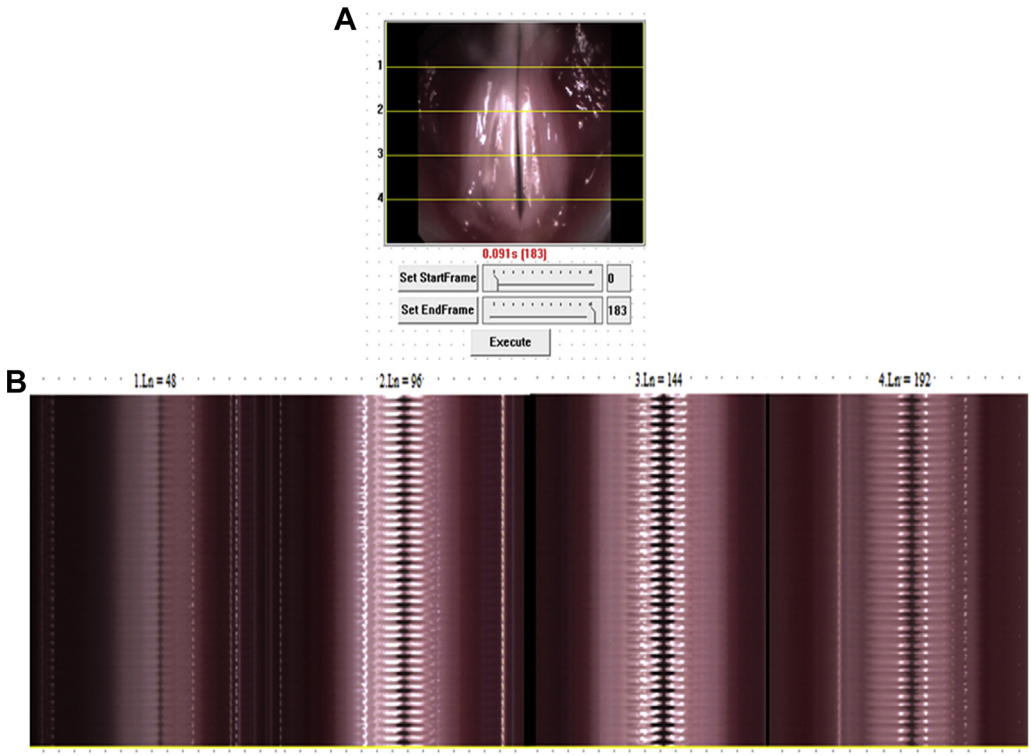

FIGURE 2. The postprocessing of laryngeal color high-speed video-endoscopic imaging and digital kymography (DKG). The anterior part of the larynx is on the bottom. As shown previously, the four levels of the canine vocal folds were analyzed (**A**) and converted to the kymographic images (**B**) with Kay's image processing software (*KIPS*).