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Real-time dual visualization of two different modalities for the evaluation of vocal fold vibration – Laryngeal videoendoscopy and 2D scanning videokymography: Preliminary report

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A B S T R A C T

Objective: Currently, various tools have been introduced for the assessment of vocal fold vibration: laryngeal videolaryngoscopy (LV), videokymography (VKG), high speed videoendoscopy (HSV), digital videokymography (DKG), and 2D scanning videokymography (2D VKG). Among these, the authors have recently designed a dual modality examination system using LV and 2D VKG for more detailed information regarding the vibrations of the vocal folds. The clinical availability of this hybrid system offers medical imaging departments a range of potential advantages in the evaluation of vocal fold vibration. The obvious benefit of simultaneous acquisition is the improved integration of information that allows not only optimal anatomic localization, but also physical movement patterns. Other advantages include the lessened inconvenience to patients due to no longer requiring repeated examinations and shortening the examination time, and increased profitability. The purpose of study was to identify the efficacy of real-time dual examination of two different modalities for the evaluation of vocal fold vibration in human subjects and vocal fold vibration simulator.

Methods: One vocally healthy subject and three patients with vocal fold nodules, a vocal cyst, and vocal fold paralysis took part in this study. The vibratory patterns of the vocal folds were visualized using simultaneous real-time examination of two different modalities. Additionally, qualitative and quantitative analyses of the dual LV and 2D VKG images were performed.

Results: Real-time dual examination using a two modality system provided high definition images of the vibratory movements of the vocal folds. By assessing the obtained images, we confirmed that the dual modality examination method was useful in the evaluation of pathologic vibratory patterns, even in non-periodic phonation.

Conclusion: The present system might improve the understanding of the processes of vocal fold vibration and make a contribution to pathologic voice research, as well as clinical practice.

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1. Introduction

There are various endoscopic methods for the evaluation of the vocal cord vibration, such as laryngeal videoendoscopy (LV), laryngeal videostroboscopy (LVS), high-speed videoendoscopy (HSV), line scanning videokymography (VKG), digital kymography (DKG), and 2D scanning videokymography (2D VKG) [1–6].

As each tool provides unique information to laryngologists, two or three methods are often used to evaluate the vocal folds in order to differentiate between voice disorders. Each method has its own advantages and disadvantages. There has been an effort to complement the limitations of each method of examination by implementing dual examinations.

Qui and Schutte [7] introduced a new simultaneous VKG system, which displays images of laryngoscopy for navigation purposes, and line scanning kymography at the same time. Compared with the existing VKG, this system was designed for observing laryngoscopic and kymographic findings simultaneously and the examination sensitivity (i.e., accuracy rate) was improved. However, this system shows small blurred and overlapped images of laryngoscopy, and provides limited information regarding vocal fold vibration.

Hillman and Mehta [8] tried to describe the comparison between LVS and HSV by using both simultaneously to view the vocal fold. One endoscope used for HSV captured images of the vocal fold with continuous illumination. The second endoscope used for LVS was connected to a stroboscopic light system with a trigger device. Hillman and Mehta reported that although HSV may provide more detailed information about vocal fold vibration. We designed a real-time dual examination modality using both LV and 2D VKG to investigate the vibration patterns of the entire vocal fold and overcome the limitations of previous examination methods. The reason why we used LV and not LVS in dual examination is as follows. At first, we tried to use both LVS and 2D VKG. It was impossible to synchronize the two modalities because the 2D VKG system in the present study uses a CMOS sensor with a rolling shutter type. Therefore, we had to use LV instead of LVS to generate a stroboscopic effect through auditory feedback. If we cannot use external trigger, we have to synchronize with fundamental frequency through auditory feedback.

The purpose of study was to identify the efficacy of a real-time dual examination system using LV and 2D VKG for the evaluation of vocal fold dynamics in a vocally healthy participant and pathological case. Additionally, qualitative and quantitative analyses were performed on the same participants.

2. Materials and methods

2.1. Preliminary experimental set-up using vocal fold vibration simulator

2.1.1. Design of vocal fold vibration simulator

The simulator was implemented to observe moving images at 100–500 Hz using both a full-high definition (HD) videoendoscopic camera (CCD sensor with global shutter, USC-700HD, U-medical Co., Korea) and full-HD 2D VKG camera (CMOS sensor with rolling shutter, USC-710HD, U-medical Co., Korea). Additionally, the simulator was a woofer speaker (SR-100A50, Sammi Sound Technology Corporation, Korea) connected to a function generator that was capable of introducing a variable frequency via an amplifier (MQ-L420, Samsung, Korea). The function generator (Function generator, Keuwl, UK) was usually an electronic test equipment plus software. It was used to generate different types of electrical waveforms over a wide range of frequencies. We drew a white line on the surface of the woofer speaker and then observed the vibratory patterns according to the change of frequency (Fig. 1A).

2.1.2. Results of preliminary experiment using vocal fold vibration simulator

Fig. 2 of A and B images taken by dual camera system at 125 Hz were fixed. Images taken in the range of 125 ± 3 Hz revealed a slow moving *straight white line* in videoendoscopy, and move up (128 Hz) and down (122 Hz) of *curved white lines* in 2D VKG. This phenomenon is referred to as the stroboscopic effect. The images obtained at 133 Hz revealed overlapping, blurred motions of the *curved, spiral, twisted white lines* in 2D VKG due to phase differences.

On the basis of the results of the preliminary experiment, the most effective targeted frequency range was around the multiples of the cameras' frame rate (25 FPS) $\pm$ 3 Hz. The images of videoendoscopy move at different speeds according to the variation of frequency. Additionally, the images of 2D VKG move up with increasing pitch and move down when lowering the pitch (Fig. 2).

2.2. Examination of human vocal fold vibration

2.2.1. Subjects

The Institutional Review Board of Pusan National University Hospital approved this study (#E-2016057). One healthy subject (M/32, author GH Kim) and patients with vocal fold nodules (F/61), a vocal cyst (F/68), and vocal fold paralysis (M/57) were examined.

2.2.2. Real-time dual examination digital imaging

For real-time dual examination of vocal fold vibratory movement, two rigid endoscopes (5.8 mm, 70°, 8700CKA, Storz, Germany) via an attachment lens coupler (f = 16–24, MGB, Germany) were fixed by a bracket and connected to a full-HD CCD camera and CMOS camera, respectively. Recording was performed under illumination with a 300 W xenon light source (NOVA 300, Storz, Germany) at a frame rate of 25 FPS, spatial resolution of 1920 × 1080 pixels, and saved in the AVI file format (Fig. 1B). The specifications of experiment materials are presented. CCD camera included $45(W)$ mm $\times$ $45(L)$ mm $\times$ $44(D)$ mm, $245g$, CMOS camera was $29(W)$ mm $\times$ $43(L)$ mm $\times$ $29(D)$ mm, $148g$, lens coupler was $42(D) \times 44(L)$, $100g$, focal length (F = 16–24), bracket was $50(W)$ mm $\times$ $60(L)$ mm $\times$ $20(D)$ mm, $100g$, and endoscope was $190(L) \times 5.8(D)$, $50g$. Total weight of the dual camera system was about $800g$ (including two endoscopes and two lens couplers). In order to overcome this limitation, we