Efficacy of Two-dimensional Scanning Digital Kymography in Evaluation of Atrophic Vocal Folds

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Summary: Objective. The purpose of this study was to evaluate the clinical feasibility and diagnostic accuracy of two-dimensional scanning digital kymography (2D DKG) in patients with vocal cord atrophy before and after treatment.
Materials and Methods. We analyzed the characteristics of vocal fold vibration in five patients with unilateral vocal fold paralysis and five patients with presbyphonia. In patients with vocal cord paralysis, the status before and after intracordal injection was compared. Furthermore, in patients with presbyphonia, we compared the status before and after voice therapy (Seong-Tae Kim's laryngeal calibration technique). Quantitative parameters such as amplitude and phase symmetry indices, jitter, shimmer, noise-to-harmonic ratio, and maximum phonation time and qualitative parameters such as Voice Handicap Index, glottal gap, amplitude, and phase difference were used to evaluate the pre- and post-treatment status.
Results. In cases of vocal cord paralysis, vibratory changes of the vocal folds before and after intracordal injection could be identified immediately using 2D DKG. In overcorrection cases, all of the measured parameters were poor except for improvement of the glottal gap. In addition, 2D DKG showed appropriately the changes in vocal cord vibration before and after voice therapy in patients with presbyphonia.
Conclusion. Two-dimensional DKG may be a useful diagnostic tool in evaluation of the vibratory characteristics of entire vocal cords. In addition, it may also play a role in providing a decision for treatment modalities.
Key Words: Two-dimensional scanning digital kymography–Vocal cord–Atrophy–Paralysis–Presbyphonia.

INTRODUCTION

Glottal insufficiency is one of the common causes of voice disorders and is often encountered in clinical practice.[1] It can be accompanied by vocal fold atrophy, scarring, sulcus formation, etc. Among these, vocal fold atrophy occurs most frequently, either as a consequence of aging or because of nerve injury. Vocal fold atrophy is caused by loss of thyroarytenoid muscle, affecting one or both vocal folds. As a result, vocal cord vibration is affected, and the gating function of the cords is degraded. Treatment for vocal fold atrophy is performed according to the cause of the conditions. Voice therapy is the main treatment for presbyphonia, but intracordal injection is preferred for unilateral vocal fold paralysis.[2]

Evaluation of vocal fold atrophy is necessary both before and after treatment. Of the available evaluation methods, direct observation of vocal fold vibration is the most effective. Laryngeal videostroboscopy can be used for this purpose; however, the images that it generates are not real, because it builds images by collecting images from different cycles. It cannot be used to examine vocal cord vibration in cases of severe dysphonia or short breathing, because it depends on steady and stable vibration.[3] Laryngeal high-speed videoendoscopy (HSV) is a possible substitute, but this approach also is difficult to use for assessing subtle vibratory changes of the vocal cords.[4] To solve these problems, functional imaging modalities using high-speed videoendoscopic images such as digital kymography (DKG),[5] strobovideokymography,[6] and two-dimensional scanning digital kymography (2D DKG),[7] as well as assessment of glottal area wave form,[8] glottal width pattern,[9] and laryngeal topography[10] have been introduced. Among these functional modalities, DKG appears to be the simplest and most accurate tool for evaluating subtle vibratory changes in the vocal folds. However, none of these procedures except 2D DKG can properly represent the vibration of the entire vocal cord. Kang et al[7] developed 2D DKG in 2017 and introduced its clinical applicability.

The purpose of this study was to investigate the usability of 2D DKG as a diagnostic tool for discriminating vibratory changes of the entire vocal cords before and after treatment.

MATERIALS AND METHODS

Subjects

For generation of 2D DKG image using HSV, one normophonic male participant (35-year-old) and one male participant with focal vocal cord atrophy (27-year-old) were enrolled. For comparisons of pre- and post-treatment status using 2D DKG, five patients (mean age 60.8 years, range 50–76 years) with unilateral vocal cord paralysis and five patients with presbyphonia with bilateral vocal cord atrophy (mean age 67.8 years, range 62–73 years) participated.

Instrumentation

An HSV system was used to assess vocal cord vibration. A black and white digital complementary metal-oxide-semiconductor camera with global shutter (USC-700MF, U-medical, Korea) was

Accepted for publication December 18, 2017.
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Journal of Voice, Vol. ■■, No. ■■, pp. ■■-■■
0892-1997

https://doi.org/10.1016/j.jvoice.2017.12.011

connected to a desktop personal computer through a USB 3.0 port. A 4-mm diameter, 70°-rigid laryngoscope (8700 CKA, Storz, Germany), a zoom coupler (f = 16–34 mm, MGB, Germany), and a 300-watt xenon light source (NOVA 300, Storz, Germany) were used for examination. Images were recorded at a frame rate of 1500 frames per second with a spatial resolution of 208 × 304 pixels in an 8-bit grayscale format. The sequence of images was saved in an AVI file format. To obtain 2D DKG images from the HSV system, we used the multifunctional laryngeal examination system developed by Kang et al.[7] Voice analysis was performed using a multidimensional voice program (MDVP Model 4500, KayPENTAX, Lincoln Park, NJ).

Generation of 2D DKG image using HSV

Two-dimensional DKG was constructed by algorithm that concatenated sequentially vertical pixel row extracted from each frame of the high-speed videoendoscopic images to generate a 2D DKG.

Figure 1 shows images created using 2D DKG with different "vertical pixel row" numbers. This is defined in terms of the number of vertical pixel row that were used for creating the 2D DKG images. "One vertical pixel row" means that one vertical row of pixels from every original high-speed videoendoscopic image was used for constructing a 2D DKG image. The 2, 3, 4, and 5-pixel row images were constructed in the same way, except that the specified number of vertical pixel row was used. As the number of vertical pixel rows increases, only the time resolution increases at the same frame per second. With this technique, 2D DKG images could be constructed for the entire vocal fold in quasi-real time. Because the raw HSV images were stored, the vertical pixel row setting could be altered either quasi-real-time or post processing. In our study, 2D DKG images were constructed using two vertical pixel rows, which are commonly used.

Procedures

The intracordal injection was performed by transcricothyroid technique while guiding the larynx by flexible laryngoscopy in patients with vocal fold paralysis. All procedures were performed with the patient awake at the outpatient clinic. A straight or bent needle is inserted under the inferior margin of the thyroid cartilage and angled up and lateral toward the side to be injected. After confirmed that the needle was properly inserted into the Reinke space, hyaluronic acid was injected for vocal augmentation. Voice therapy using Seong-Tae Kim's laryngeal calibration technique (SKLCT)[11] was applied for patients with presbyphonia, in total of four sessions, once every week. SKLCT is a treatment program designed to improve the voices of patients with atrophic vocal cord lesions, by combining various physiological voice training techniques (such as laughing voice and inhalation phonation) with step-by-step training in singing.

In all cases, the subjects were instructed to phonate the sustained vowels /i/ or /e/, at a comfortable pitch and volume. Two-dimensional DKG, voice recordings, and Korean Voice Handicap Index-10 questionnaires[12] were administered before and after treatment, and in cases of paralysis, immediately after intracordal injection. Voice recording was performed using PCquire (Scicon R&D, Beverly Hills, CA) simultaneously during 2D DKG examination.

Assessment

Evaluation of the vibration pattern of the voice folds, using a 2D DKG image, was performed by a speech-language pathol-

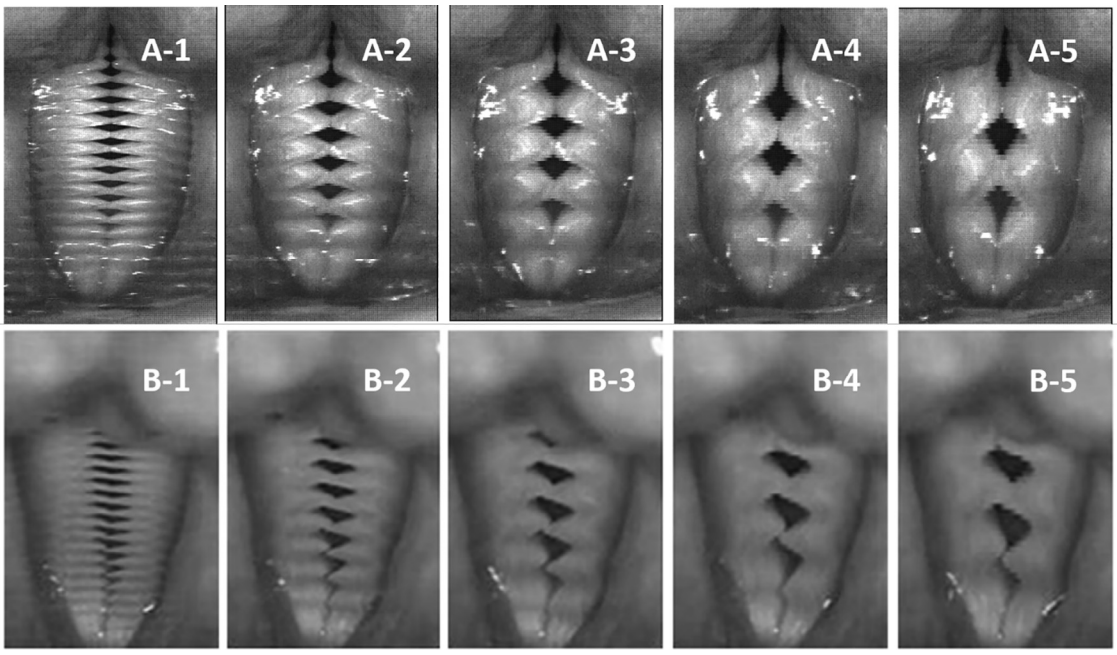

FIGURE 1. Two-dimensional DKG images constructed using different numbers of vertical pixel row. (**A**) Normophonic participant (male, 35-year-old); (**B**) left focal vocal cord atrophy (male, 27-year-old). (**A-1** and **B-1**) One-pixel row 2D DKG images; (**A-2** and **B-2**) 2-pixel row; (**A-3** and **B-3**) 3-pixel row; (**A-4** and **B-4**) 4-pixel row; (**A-5** and **B-5**) 5-pixel row.