Vocal Fold Vibratory Changes Following Surgical Intervention

*Wenli Chen, †Peak Woo, and ‡Thomas Murry, *Brooklyn, †New York, New York, and ‡Loma Linda, California

Summary: High-speed videoendoscopy (HSV) captures direct cycle-to-cycle visualization of vocal fold movement in real time. This ultrafast recording rate is capable of visualizing the vibratory motion of the vocal folds in severely disordered phonation and provides a direct method for examining vibratory changes after vocal fold surgery. The purpose of this study was to examine the vibratory motion before and after surgical intervention. HSV was captured from two subjects with identifiable midvocal fold benign lesions and six subjects with highly aperiodic vocal fold vibration before and after phonosurgery. Digital kymography (DKG) was used to extract high-speed kymographic vocal fold images sampled at the midmembranous, anterior 1/3, and posterior 1/3 region. Spectral analysis was subsequently applied to the DKG to quantify the cycle-to-cycle movements of the left and the right vocal fold, expressed as a spectrum. Before intervention, the vibratory spectrum consisted of decreased and flat-like spectral peaks with robust power asymmetry. After intervention, increases in spectral power and decreases in power symmetry were noted. Spectral power increases were most remarkable in the midmembranous region of the vocal fold. Surgical modification resulted in improved lateral excursion of the vocal folds, vibratory function, and perceptual measures of Voice Handicap Index-10. These changes in vibratory behavior trended toward normal vocal fold vibration.

Key Words: High-speed videoendoscopy–Vocal fold vibration–Phonosurgery–Spectrum.

INTRODUCTION

Vocal fold surgery is the treatment of choice for dysphonia that does not resolve with medical or behavioral treatments.[1] Outcomes of surgery have traditionally been assessed by patient reports, acoustic, and aerodynamic measures of change and by visual inspection using standard endoscopy or videostroboscopy. Until recently, only videostroboscopy provided direct observation of the change in vibration after surgery. However, videostroboscopy fails to capture the cycle-to-cycle vibratory motion of the vocal folds and objective vibratory information.[2,3] Thus, it is difficult to fully assess the changes after surgical intervention of the vocal folds, especially when the presurgical assessment is not adequately captured on videostroboscopy. This is often the case with vocal fold scar and vocal fold paralysis because of the lack of a quasiperiodic signal input to the stroboscope.

High-speed videoendoscopy (HSV) captures direct visualization of vocal fold movement in real time at frame rates of 2000–10 000 frames per second.[4–7] Therefore, this ultrafast recording rate is capable of visualizing the entire cycle-to-cycle vibratory motion of the left and right vocal folds individually in normal speaking adults[4–7] and in disordered phonation.[8,9] Digital kymography (DKG) uses HSV to examine the precise vibratory characteristics of each vocal fold at multiple locations of the vocal folds.[2,10,11] The resulting values can be represented as a vibratory spectrum.[12] In the vibratory spectrum, spectral power in the fundamental frequency ($F_0 = H_1$) has been associated with the degree of vocal fold excursion, whereas the energy of the higher harmonics has been associated with the discontinuity that occurs with vocal fold impact.[12,13] Therefore, DKG spectrum presents as a useful tool to quantify direct cycle-to-cycle vocal fold vibration and the specific vibratory changes after surgical intervention. Spectral analysis of DKG has been previously examined in normal vocal fold vibration.[12] However, little is known on disordered vocal fold vibratory spectrum and the changes in vibratory behavior after surgical intervention. This preliminary study uses DKG spectrum to examine the vocal fold vibratory behavior before and after surgical intervention sampling at the midmembranous, anterior 1/3, and posterior 1/3 region of the vocal fold. Two subjects with identifiable midvocal fold benign lesions and six subjects with highly aperiodic vocal fold vibration were studied before and after phonosurgery.

METHODS

Eight adult subjects participated in this presurgical and postsurgical intervention study. Refer to Table 1 for laryngeal etiology, age, diagnosis, and the type of surgical intervention. Subjects were diagnosed by a board-certified otolaryngologist. Subjects produced tokens /i/ at a comfortable pitch and loudness.

High-speed video recording

HSV was recorded using Kay Elemetrics high-speed digital imaging (HSDI) system (KayPENTAX Photronmotion; Pentax Medical, Montvale, NJ), which consisted of a 90-degree rigid endoscope (Model 9100) and a 300-Watt Xenon light source. The HSDI system captured gray-scale images at a rate of 2000 frames per second with a spatial resolution of 256 × 120 pixels rotated to a vertical position for capture. The HSV samples were obtained when the examiner observed a clear

Accepted for publication March 24, 2015.
A version of the article was presented at the 43rd Annual Symposium Care of the Professional Voice, Philadelphia, PA, June 1, 2014.
From the *Department of Rehabilitation, NYU Lutheran Medical Center, Brooklyn, New York; †Department of Otolaryngology–Head and Neck Surgery, Icahn School of Medicine at Mount Sinai, New York, New York; and the ‡Department of Otolaryngology–Head and Neck Surgery, Loma Linda University, Loma Linda, California.
Address correspondence and reprint requests to Wenli Chen, Department of Rehabilitation, NYU Lutheran Medical Center, 150 55th Street, Station 3-06, Brooklyn, NY 11220. E-mail: wc2416@tc.columbia.edu
Journal of Voice, Vol. ■, No. ■, pp. 1-4
0892-1997/$36.00

http://dx.doi.org/10.1016/j.jvoice.2015.03.016

Journal of Voice, Vol. ■, No. ■, 2015

TABLE 1.
Information on Pathologic Group, Age, Diagnosis, and Type of Surgical Intervention Received

Subject	Age	Diagnosis	Diagnostic Information	Surgical Intervention
M1	42	Polyp	L VF polyp	Polyp excision cold instruments
M2	47	Polyp	L VF polyp	KTP laser
S1	85	Scar	R VF scar with hyperkeratosis	KTP laser
S2	71	Scar	L VF scar with recurrent keratosis	KTP laser
S3	68	Scar	L VF scar with R VF bowing	KTP laser
P1	45	Paralysis	R VF paralysis with R sulcus vocalis	Injection laryngoplasty
P2	49	Paresis	L VF paresis	Injection laryngoplasty
P3	67	Paresis	L VF paresis	Injection laryngoplasty

Abbreviations: KTP, potassium titanyl phosphate; VF, vocal fold.

and full view of the larynx. Six continuous 2-second tokens were recorded. The three best tokens with a clear and full view of the larynx were saved onto the hard drive for analysis. A more detailed description of the recording sessions was previously reported.[12]

Data analysis

Kymography image processing. HSV samples were preprocessed (ie, adjusting brightness and contrast) using a video-editing software (*VirtualDub* Version 1.9.11) to optimize contrast between the glottis and the vocal fold. Image rotation was implemented to ensure vertical alignment of the image. A 400- to 500-frame video segment that captured a full view of the vocal folds with minimal movement of the subject was extracted from the recorded HSV samples. Kay's Image Processing Software (KIPS; Pentax Medical, Montvale, NJ, model 9181) was used to generate the kymogram. Three transverse lines were placed across the glottis to sample the anterior 1/3 portion, the posterior 1/3 portion, and the midmembranous portion of the vocal folds (Figure 1A). Digital kymograph was then created at the three regions along the vocal fold (Figure 1B). Edge detection was subsequently applied to delineate and trace the vocal fold edges (Figure 1C). Manual correction function was used to ensure correct delineation of the vocal fold edges, as appropriate. Kymograph edge analysis function was applied on the kymogram afterward. The resulting values were kymograph edge data (KED), which depicted the coordinate values of the left and right edges of the vocal fold presented across time (Figure 1D). Subsequently, Fourier transform function was applied to the KED, resulting in a spectrum ranging from 0 to 1000 Hz for the left and right edges of the vocal folds (Figure 1E).

Spectral data analyses

Six values were obtained from each spectrum for quantitative analysis: the frequency and peak power values of the fundamental ($F_0 = H_1$), second harmonic (H_2), and third harmonic (H_3). Twenty-five percent of the postprocessed 500-frame HSV tokens were randomly selected and reanalyzed by the same experimenter to evaluate error of measurement. Comparison of the H_1, H_2, and H_3 values between the original and reanalyzed sample yielded a reliability of 85%.

The following vocal fold vibratory parameters were examined at baseline and postintervention: (1) total spectral power; (2) spectrum shape; (3) spectral power symmetry; and (4) Voice Handicap Index (VHI)-10. Total spectral power was determined by summing the spectral peak values of H_1, H_2, and H_3 all together. Spectrum shape was determined by summing the spectral power individually (ie, sum of H_1, sum of H_2, and sum of H_3) across all subjects. Spectral power asymmetry examined the differences between the left versus right spectral peak power divided by the sum of the left and right spectral power, expressed as a percentage. Finally, VHI-10 was administered to examine subject's perception of their voice handicap.

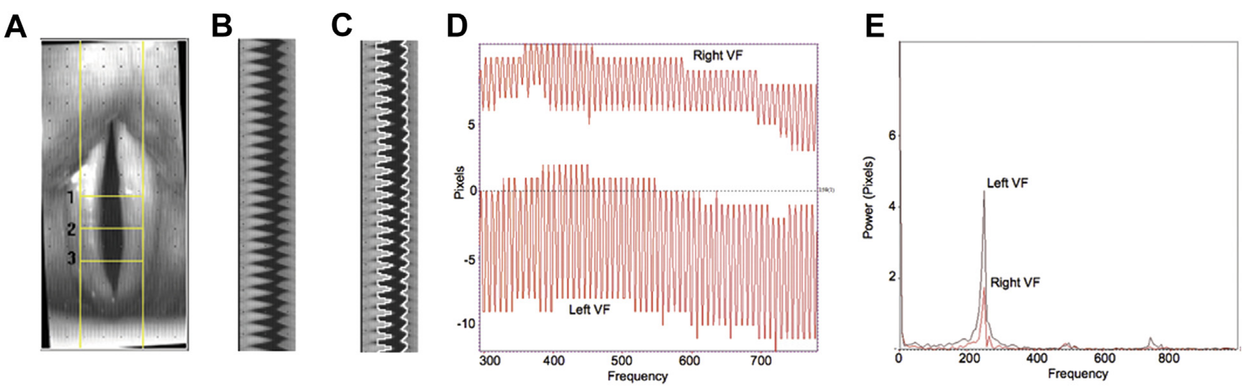

FIGURE 1. (**A–E**): Methods to obtain spectral analysis of digital kymography in subject P2. (See text for descriptions.)