Comparative Analysis of Vocal Fold Vibration Using High-Speed Videoendoscopy and Digital Kymography

*Paula Belini Baravieira, †Alcione Ghedini Brasolotto, ‡Adriana Hachiya, ‡Marystella Tomoe Takahashi-Ramos, ‡Domingos Hiroshi Tsuji, and *Arlindo Neto Montagnoli, *Sao Carlos, †Bauru and ‡São Paulo, São Paulo, Brazil

Summary: Objectives. To compare high-speed videoendoscopy (HSV) and digital kymography (DKG) in the vocal fold vibration analysis of normophonic women with no vocal fold abnormalities.

Study Design. Prospective study comparing quantitative parameters extracted by HSV and DKG.

Methods. Eighteen normophonic women whose age ranged from 18 to 45 years participated in the study. The procedures comprised HSV and DKG of the medial line of the vocal folds. The parameters evaluated were fundamental frequency (F_0), open quotient (OQ), and duration of vibration cycle phases (open phase, closed phase, opening phase, and closing phase).

Results. The F_0 results of HSV and DKG were similar. However, significant differences were found in both duration of vibration cycle phases and OQ, indicating a longer open phase in the vocal fold vibration when this phase was measured by HSV.

Conclusions. The results emphasize the need to set up different normative threshold values for both HSV and DKG.

Key Words: High-speed videoendoscopy–Kymography–Voice analysis.

INTRODUCTION

High-speed videoendoscopy (HSV) is a laryngeal imaging examination, the main advantage of which is that a camera captures 4000 frames per second, resulting in a visualization of the true, cycle-to-cycle nature of phonation.[1–9] Digital kymography (DKG) is defined as an HSV-extracted kymography that selects the line of interest more easily and accurately than conventional kymography due to its recording form, which allows the professional to choose a particular line of the vocal folds to be scanned off-line.[1,10] Both HSV and DKG provide objective data on the intracycle periods of vocal folds vibration and have been used in many studies as complementary methodologies.[3,11–14]

However, the methods assess vocal folds vibration patterns differently. HSV analyzes the behavior of long vocal folds vibration lengths through a graphing of the glottal area waveforms (GAWs). On the other hand, DKG analyzes the behavior of a single, selected location of vocal folds vibration through a line scanning of laryngeal images at high speed.[11] This line is perpendicular to the glottal axis and often in the maximum vibratory amplitude. At a selected line scanning, a single image represents the movements of the vocal folds in time.[15] Analysis by DKG reduces the amount of external information provided and makes the visual evaluation of the vocal folds vibration easier and more focused.[13] Furthermore, this methodology facilitates the visualization of differences in the vibration pattern between the right and left vocal folds.[11] On the other hand, DKG hampers the analysis of complex movements of the vocal folds as it requires several separate measurements from multiple line scannings of vocal folds and cannot quantify the glottal area.[11]

DKG has parity with the images of HSV; therefore, it is possible to select the same cycles of vocal folds vibration to be analyzed by both methods.[10,12,13] Despite the use of the same vibration cycles for the calculations of vibration parameters, professionals must interpret the results cautiously because it is still unclear if these methodological differences generate distinct results in the analysis of vibration cycle phases. It is known that the chosen scanning line of the DKG influences the measurement of the vibration cycle phases and, consequently, the open quotient (OQ).[16–20] Several studies use the medial line of the vocal folds where the maximum vibration amplitude occurs, determining that this location is the most representative place for kymographic imaging of the vocal folds.[21] Therefore, does the DKG analysis of the medial line of the vocal folds represent the vibration cycle phase most similar to the GAW of the HSV?

Several studies on such methodologies have been published that show normative data from DKG and HSV.[16,22,23] However, the similarities and differences between these methodologies are still unclear in the quantitative analysis of vocal folds vibration. This comparison is essential to understand whether the normative threshold value is the same or different in both methods, which is the key for the correct interpretation of the results and successful clinical use of the methodologies.

This study compares HSV and DKG in the vocal folds vibration analysis of normophonic women with no vocal fold abnormalities.

MATERIALS AND METHODS

Eighteen normophonic women aged between 18 and 45 years (mean = 27 years; standard deviation [SD], 5 years) with normal voices and no vocal fold abnormalities were recruited for the analysis. The study was approved by the Institutional Review Board (n°: 257/2010—Ethics Committee of São Carlos University) and informed consent was obtained.

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From the *Bioengineering Graduate Program EESC/FMRP/IQSC, University of São Paulo, Sao Carlos, São Paulo, Brazil; †Department of Speech-Language Pathology and Audiology, Bauru School of Dentistry, University of São Paulo, Bauru, São Paulo, Brazil; and the ‡Department of Otorhinolaryngology, University of São Paulo, School of Medicine, São Paulo, São Paulo, Brazil.

Address correspondence and reprint requests to Paula Belini Baravieira, Rua Galvão de Castro 13-40 (Bl.G - Apt. 52), Bauru, São Paulo 17030-026, Brazil. E-mail: paulabaravieira@usp.br

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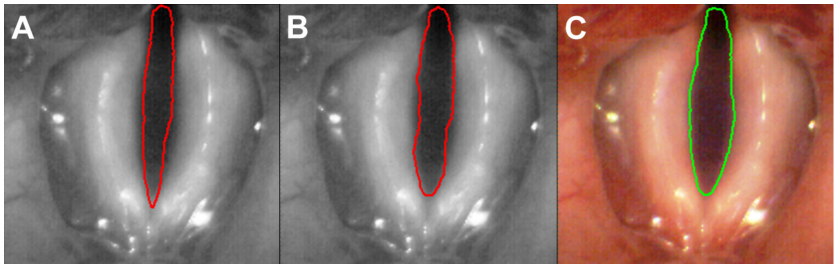

FIGURE 1. Identification of the vocal fold edges by the active contour model.[19] (**A** and **B**) Process of contour expanding to the vocal folds edges. (**C**) Delimited boundary of the vocal folds.

The inclusion criteria were to be of female gender, aged between 18 and 45 years, with an absence of vocal complaints, with a Voice-Related Quality of Life score above 97.1 (cut-off value for normophonics),[24] absent of vocal fold pathology or supraglottic constriction in the laryngoscopic examination, and to have adequate classification of voice quality in an auditory-perceptual assessment by three different speech pathologists, implying a score of vocal deviation from 0 to 34 mm on a visual analog scale.[25]

Subjects with endocrine disorders (including menopause), histories of complaints of dysphonia and/or vocal pathology, previous vocal fold surgeries, smoking habits, significant use of alcohol, allergic reactions or infections, and laryngeal signs of gastroesophageal reflux were excluded from the study.

Procedures

The HSV examination was recorded at Clinics Hospital, Sao Paulo University Medical School. Participants were instructed to produce sustained phonation of /ɛ/ at a comfortable pitch and loudness. The HSV was recorded by High-Speed Endocam Complete System (model Endocam-5562; Richard Wolf GmbH, Knittlingen, Germany) coupled with a 70° rigid endoscope. The system captured at 4000 frames per second with 256 × 256 pixel spatial resolution.

For the analysis of the vocal folds vibration, the HSV recordings were segmented by the active contours method proposed by Kass et al[26] (Figure 1). This method delimits the vocal folds edge automatically, providing a graph of the GAW (Figure 2).

A static image of the medial line of the vocal folds at the maximum vibration amplitude was used for the DKG analyses of all subjects. The DKG was generated from the images of HSV available in the "High-Speed Endocam Complete System."

The following parameters of the vocal folds vibration were calculated from the analysis of the GAW and DKG:

- Vibration cycle phases: open phase (TFA), closed phase (TFF), opening phase (ta), and closing phase (tf). These phases describe a vibration cycle that is divided into two main phases: open and closed phase. The open phase, which occupies most of the cycle, is divided into phases of opening and closing (Figure 2).[27]
- Fundamental frequency (F_0): calculated by ratio 1 divided by the cycle period (1/T).
- OQ: represented by the TFA/T ratio.[28]

The mean value of five successive vibration cycles was considered in the calculation of the vibration parameters. Subsequently, to analyze the vocal behavior of the group, both averaged and SDs were calculated and compared.

Student *t* test was used for a comparative statistical analysis between HSV and DKG for all parameters. The power of the test was set at 80% and alpha at 5% (minimum difference 0.1 and SD 0.1), leading to a value of the sample size of 17 subjects. To have a safety margin, we stipulated that "n" equals 18 subjects.

RESULTS

The results showed significant differences between the methodologies in all vibrational parameters, except for F_0, which was similar in both HSV and DKG ($P = 0.878$—Student *t* test), with averages of 207.0 ± 15.5 Hz for HSV and 207.4 ± 16.6 Hz for DKG (Figure 3). However, differences were observed when the period was divided into opening, closing, open, and closed phases. The mean values of the vibration cycle phases are shown in Figure 4, and the statistical analysis is shown in Table 1.

Regarding the OQ of the vocal folds, average values of 0.68 ± 0.12 and 0.55 ± 0.09 were found for HSV and DKG,

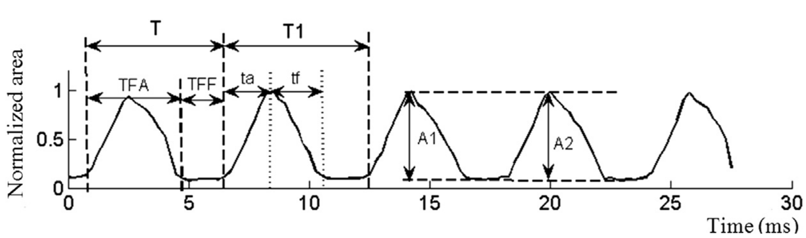

FIGURE 2. Quantitative measurements extracted from the graph of the GAW used in the calculation of vibration parameters. T and T1, periods of glottal cycles; TFA, open phase; TFF, closed phase; ta, opening phase; tf, closing phase; A1 and A2, maximum area in the vocal fold vibration.