On vibration properties of human vocal folds
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Variability of Vibration of Normal Vocal Folds as Seen in Videokymography

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Variability of Vibration of Normal Vocal Folds as Seen in Videokymography

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ABSTRACT

Videokymography (VKG) is an easy, powerful and cost-friendly method to observe the variability of the vocal fold vibration. It is important to realize, however, that the measuring position is an essential factor here. It should be checked at which position along glottal length the measurement is taken as well as whether the glottal axis is perpendicular to the measuring line. The vocal fold vibration changes with loudness, pitch, type of phonation, voice register. In some cases, the vibration of normal vocal folds may become irregular (such as in vocal fry, breathy voice, or coughing). As normal larynges are rarely ideally symmetric, one can often observe some degree of phase delay of one vocal fold with respect to the second one, under extreme conditions (as, e.g., high pitch or intensity) the vibrations of the two vocal folds can also get desynchronized. Understanding better the vibration of normal vocal fold should improve our ability to recognize and distinguish various abnormalities and pathologies.

INTRODUCTION

Videokymography (VKG) is a new high-speed imaging technique for investigation of vibration developed especially for examination of vocal fold vibrations. The system uses a modified B&W video camera which is able to work in two modes – normal (50 or 60 images/s in CCIR or NTSC norm, respectively) and high-speed (nearly 8 000 images/s). In the normal mode the system functions as a normal commercial video camera. In the videokymographic mode the camera selects just a single horizontal line from the whole image and monitors it with a high speed. A new, videokymographic image is composed by putting the successive high-speed line images below each other. This image monitors the vibration of the selected part of the vocal folds in time. Both the normal as well as high-speed images can be recorded on a standard videorecorder which makes this technique cost-friendly. A more detailed explanation of the principle of the VKG method can be found elsewhere [1–3].

Such features as amplitudes of vibration, asymmetry in phase and amplitude, vertical phase differences or mucosal waves are nicely visible in VKG [1–3]. Similarly as in classical high-speed recordings or stroboscopy, various quotients, such as, e.g., open quotient (OQ: defined as the duration of the open phase divided by the duration of the glottal cycle) [4–6] can be utilized to describe the variability of the observed vibration. The technique is suitable for examination of all kinds of vocal fold vibrations, including rough, breathy, hoarse or diplophonic which makes it promising for clinical practice (see [7, 8]). In order to explore the VKG technique for clinical purposes, however, it is useful to know the variability of vibration in normal vocal folds as shown by this method.

The present study is retrospective: the data from normal subjects were gathered during numerous observations and experiments carried out in the Groningen Voice Research Lab and Center for Communication Disorders, Medical Healthcom in Prague since the development of the VKG method in 1994.
FACTORS RELATED TO VARIABILITY OF THE VIDEOKYMOGRAPHIC VIBRATORY PATTERN OF THE VOCAL FOLDS

Generally two basic factors should be taken into account when considering the variability of the VKG vibratory pattern: the measuring position and the variability of the vocal fold vibration itself.

A) Measuring position
A.1) Position of the measuring line along glottal length
The vibratory patterns of the anterior, middle and posterior part of the vocal folds are generally different. There are differences in amplitudes (usually greatest in the middle) as well as in the duration of the various phases of the cycle (closed, open, opening, closing) which lead to different values of, e.g., open or speed quotient [7, 9].

A.2) Rotation angle of the measuring line with respect to glottal axis
The vocal fold axis may sometimes appear somewhat rotated. The oblique position of the glottal axis with respect to the measuring line is not advantageous since it may cause artifacts in the measured vibratory pattern (e.g., illusory asymmetry). In order to avoid this, the measuring line should be perpendicular to the glottal axis.

B) Change of voice quality
B.1) Loudness, pitch, type of phonation, register
There is large variability in the phonatory adjustments which results in a considerable variability of the vocal fold vibration. Together with aerodynamic adjustments, various laryngeal adjustments lead to different loudness (SPL), pitch (frequency), as well as type of phonation (breathy, normal, pressed, etc.). Videokymography enables an easy observation of changes in the vibratory pattern related to these factors. Figure 1 demonstrates the change of loudness as reflected in VKG.

One of the most controversial subjects related to normal voice are vocal registers. Fig. 2 shows vibratory pattern of the chest and falsetto registers. The differences among these three types of phonation are clearly visible here. There is an effort to explore VKG for a more detailed description of the differences between the registers. The method appears particularly useful in observing transitions and sudden changes between the adjacent registers.

B.2) Irregularities
Normal vocal folds may also vibrate irregularly and imitate pathologic-like phonations (Fig. 3). The irregularity occurs, for instance during so called creaky voice. Fig. 3 (left) shows an example of creaky voice with a subharmonic vibratory pattern (note the double opening of the vocal folds). Within this type of phonation the vocal fold vibration is often unstable and may exhibit sudden changes, like octave jumps.

In contrast to the creaky voice in which the vocal folds are well adducted (note the long closed phases) another example of irregularity appears, for instance, when a lot of air is suddenly exhaled through rather abducted vocal folds. In this case a breathy hoarse
voice is produced (Fig. 3, middle). The vibratory pattern is very complex here, showing “ripples” in the vibration of the vocal folds. A similar pattern may appear, e.g., during coughing.

Voice irregularities can also occur due to laryngeal asymmetry. A slight phase shift of one of the vocal folds with respect to the second one is a common symptom of glottal asymmetry and can often be found in normal subjects, as demonstrated here in Fig. 1. While in Fig. 1 the asymmetry does not cause any major problem (the vibration is regular), under specific conditions (for instance at highest pitches or intensities) the asymmetry may cause that the left and right vocal folds become desynchronized and the voice sounds hoarse or diplophonic (Fig. 3, right, see also [10] for this phenomenon).

It has been known for long time that the variability of the vibration of the vocal folds themselves is very large. It has been quite difficult and lengthy, however, to evaluate the modification of the vibratory pattern of the vocal folds from the routinely used laryngostroboscopic images. Better understanding of the dynamic behavior of the normal vocal folds should be helpful in recognizing abnormalities occurring in voice disorders. Videokymography offers a relatively simple and powerful tool which can provide a more detailed useful information in this respect.

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