First Results of Clinical Application of Videokymography

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**Objectives:** Stroboscopy is based on the assumption that the vibration of the vocal folds is stable and regular. Irregular vibrations, which are common in voice pathology, cannot easily be studied and described in a reliable way. Videokymography overcomes most of these drawbacks. **Design:** The use of the recently invented videokymography for studying vocal fold vibrations in patients is introduced. **Method:** Videokymography, using a modified CCD-video camera, works in two modes: standard and high speed. In standard mode the vocal folds are displayed on a video monitor in the usual way, providing 50 images per second (or 60 in the National Television Standards Committee (NTSC) system). This is used for routine laryngoscopic and stroboscopic examination of the larynx. In high-speed mode (nearly 8000 images per second) only one line from the whole image is selected and displayed on the x-axis of the monitor; the y-axis represents the time dimension. **Results:** All kinds of vocal fold vibrations, including those leading to pathological rough, breathy, hoarse, or diplophonic voice productions can be observed. Videokymography visualizes small left-right asymmetries, open quotient differences along the glottis, lateral propagation of mucosal waves, and movements of the upper margin and, sometimes in the closing phase, the lower margin of the vocal folds. **Conclusion:** Videokymography is advantageous for a more accurate diagnosis of voice disorders. Videokymography provides a simple way to study irregular vibrations of the vocal folds. Information is directly available for further processing and allows a first-time quantification of vibrations registered. **Key Words:** Vocal fold vibration, laryngoscopy, stroboscopy, videokymography, voice disorders.

**INTRODUCTION**

Vibration of the vocal folds critically determines the quality of voice and therefore its objective evaluation and quantification are tasks of high importance. For medical purposes visual inspection of the larynx is essential and cannot be omitted. For more than 100 years stroboscopy has been used to visually study the vocal fold vibrations. The necessity of using an optical trick to slow down the movements as observed by the eye is obvious, because the vocal folds vibrate too rapidly for the whole vibratory cycle to be seen under continuous light. The stroboscope is used to create an illusory slow motion of the vocal fold. Another step forward in evaluation and quantification of the vocal fold vibration has been made hand in hand with the use of computer-integrated stroboscopic systems.¹ ²

Although stroboscopy makes it possible to investigate vibrational patterns of the vocal folds, it has a serious limitation in that it works only with periodic vibration. Every frequency disturbance of the investigated vibration disturbs the resulting stroboscopic image, making quantification difficult. Irregular vibrations of the vocal folds cannot be studied at all. In exploring the singing voice, even the occurrence of vibrato disturbs the process of visual examination to a great extent.

These problems have led to efforts to find a laryngoscopic method not limited to periodic vibrations. Larynx photokymography was designed by Gall et al.³ and later explored by Gross.⁴ The technical realization of the system has not, however, led to a commercially available form. Ultra-high-speed cinematography, first developed in the Bell Telephone Laboratories in the 1930s, has served as a research tool for many scientists. (For an overview see Hirano.)⁵ In recent years this cinematographic technique has been supplanted by digital high-speed imaging systems, which offer the most powerful methods to date for processing and evaluating the vocal fold vibration.⁶ ⁹ However, these systems use nonstandard, complex equipment that makes them prohibitively expensive for most clinicians and voice laboratories.

Recently, research was carried out in the Groningen Voice Research Lab (University of Groningen, the Netherlands) in cooperation with the Lambert Instruments Company (the Netherlands) that led to the development of a special CCD video camera. The camera can work in two

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modes. In the first mode the system functions as a normal commercial video camera—recording 50 images per second (for the European PAL [Phase Alternate Line] or SECAM [Sequentiel Coeur a Memoire] system) or 60 images per second (for the National Television Standards Committee [NTSC] system.) The second, the videokymographic mode, makes it possible to record images of a chosen cross-section of the vocal folds at a rate of 7812.5 images per second. Instead of registering the whole image of the vocal folds, this system reads just a single line of the image. The successive line images are presented in rows on a commercial TV monitor and show the vibratory pattern of the selected part of the vocal folds. The principle of videokymography was described in detail in earlier papers, together with recorded examples of vibration of normal vocal folds.\textsuperscript{10,11}

Videokymography uses a standard videolaryngoscopic set-up with a continuous light source. Both the normal and high-speed videokymographic images are recorded by means of a standard video recorder. Switching between the two modes of the camera is controlled with a foot switch.

This article compares stroboscopic and videokymographic images and shows how videokymography may be helpful in obtaining more detailed information about the vocal folds in various voice disorders.

**MATERIALS AND METHODS**

A stroboscope (Wolf 5012, Richard Wolf GmbH, Knittlingen, Germany) and a color camera (Atmos-Hitachi-Denahi KP-C250AE with control unit, Atmos Medizintechnik GmbH & Co., Lenzkirch, Germany) were used for laryngostroboscopy, a continuous light source (Wolf Auto LF 5130) and the videokymographic CCD black-and-white camera (Lambert Instruments, BV, Leutingewold, the Netherlands) were used for videokymography. A rigid endoscope (Lupenlaryngoskop, Wolf 4450.47) together with an s-VHS video recorder (Panasonic AG 7355, Panasonic-Matsushita Electric Industrial Co., Ltd., Tokyo, Japan) was used to obtain and record the images of the vocal folds in both types of examination. In some cases a zoom objective adapter (Wolf) was used to magnify videokymographic images.

Normal subjects were investigated in detail in the Groningen Voice Research Lab in the Netherlands. More than 800 patients with various functional and organic voice disorders were clinically examined in the Centre for Communication Disorders in Prague, the Czech Republic. Videokymographic measurements were preceded by detailed phoniatric examination and videolaryngostroboscopy. The laryngoscopic and laryngostroboscopic images served as a basis for selecting the line image of interest in videokymography.

**RESULTS**

**Comparison of Stroboscopy and Videokymography**

Figure 1 shows a series of stroboscopic images of vibrating vocal folds. The images display a complete vibratory cycle. Note that at the moment of the maximally closed phase the dorsal part of the glottis is completely closed, whereas in the anterior part the glottis does not close completely (first and last image in the series.)

The same type of phonation that was produced to obtain Figure 1 was repeated in order to obtain videokymographic images. By tilting the camera and thus moving the scan line from a frontal to dorsal position, it was possible to register in detail the vibratory patterns of the vocal folds at different places along the glottis. Figure 2 shows videokymograms taken from five different places of the glottis. The pictures clearly show that the vocal folds vibrate with different closing and opening time on different spots of the glottis. The open quotient (OQ)\textsuperscript{2,4,5,12} shows values of 1, 1, 0.8, 0.65, and 0.5, at the positions 1 through 5, respectively. The videokymogram indicated by #3 in this figure corresponds to the place of the largest thickness of the blood vessel, which appears in the image as a thick line following the movements of the vocal fold with a slight phase delay.

**Pathologic Vocal Folds**

The laryngoscopic image part of the images presented shows the appearance of the larynx during breathing, the stroboscopic part of the image characterizes the
vocal folds in phonation, and the videokymographic part is used to display the dynamic vibratory characteristics of the vocal folds. Taken together these images provide combined information on the characteristic features of the vibration of the vocal folds under study.

**Patient 1.** Patient 1 was a 55-year-old woman suffering from left vocal fold paralysis after strumectomy 5 years before. Her voice was perceptually evaluated as hoarse with slight breathiness. In increasing the intensity of phonation the hoarseness became more apparent and diplophonic (audible subharmonic), and bitonal sequences (two independent audible pitches) were noticed. The laryngoscopic view of the vocal folds during breathing (Fig. 3A) and phonation (Fig. 3B) revealed that the left vocal fold remained in the intermediate position and the right vocal fold was fully mobile. Stroboscopy showed glottal insufficiency and irregularities in frequency and amplitude of the vocal folds. The videokymographic image (Fig. 3C) revealed that the vocal fold at the left paretic side vibrated at a lower frequency than the right one. Irregularities of vibration were apparent on both vocal folds, which may be explained as a consequence of the left-right fold interaction. The vibration of the left paretic side appeared more stable when compared with the healthy side. Almost no closed phase could be found, a sign of glottal insufficiency. Mucosal waves were visible on the unaffected right vocal fold (marked with arrow and “w”).

**Patient 2.** Patient 2 was a 69-year-old man suffering from chronic edema of the vocal folds. His voice was perceptually evaluated as hoarse with a slight breathiness. Laryngoscopy revealed intact gross mobility of both vocal folds (Fig. 4A and B). A semispherical hypertrophy of the left ventricular fold was visible. Stroboscopy was unstable, showing glottal insufficiency, both vocal folds were vibrating, and mucosal waves on the left vocal fold were present. A movement of the edema instead of the mucosal waves was observed on the right vocal fold. These findings are directly reflected in the videokymographic image (Fig. 4C), which shows approximately two cycles of phonation (frequency, approximately 100 Hz). Propagation of the mucosal waves on the left side was visible, and the light reflection on the right vocal fold corresponded to the vibration of the edema. The vibration demonstrated a high degree of asymmetry, the left vocal fold was 140° delayed in phase with respect to the right one, which caused glottal insufficiency.

**Patient 3.** Patient 3 was a 58-year-old man with a polyp on the right vocal fold. His voice was evaluated as husky with slight breathiness, produced with excessive effort. Laryngoscopy (Fig. 5A) showed the polyp placed in the middle third of the membranous part of the right vocal fold at its medial border. Also, a furrow on the opposite vocal fold was visible (marked by an arrow). Stroboscopy showed that both vocal folds were able to vibrate, with the polyp interposed between the vocal folds during the vibration (Fig. 5B). The vibratory amplitude of both vocal folds was shortened because of chronic inflammation. An irregular linear gap remained in the closed phase ven-
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Fig. 5. Laryngoscopic images of a male subject with a polyp of the right vocal fold. (A) Breathing position. The arrow points to a furrow visible on the left vocal fold. (B) Stroboscopic view of the vocal folds during phonation demonstrating how the polyp interposes between the vocal folds. The two lines show measuring positions for the two videokymographic images taken from the same phonation. (C) Videokymography in the vicinity of the polyp. A very long closed phase is registered. (D) Videokymography at the position next to the polyp. The vocal folds remain separated. The arrow points to moment of disturbance during the phase of the most medial position of the vocal fold that may be attributed to the influence of collision forces between the polyp and the left vocal fold as well as to the presence of the furrow on the left vocal fold.

Fig. 6. Larynx of a male subject with partial cordectomy right and slightly approximated ventricular folds. (A) Breathing position. (B) Phonation position. (C) The videokymographic image (total time displayed, 18.4 ms) taken at a position marked by the line in B displays the vibrating ventricular folds (v), as well as the vibrating left vocal fold (f) below the ventricular folds.

bility was limited. The reddish right vocal fold was diffusely thickened and its anterior part was hidden underneath the ventricular fold. The surface of the gray, left vocal fold was smooth, diffusely thickened, and cylindrically shaped. Soft, red, slightly irregular tissue was visible on the laryngeal surface of the epiglottis, which was also diffusely thickened. Stroboscopy showed reduced vibratory amplitude of the right vocal fold; its hidden anterior part was impossible to evaluate. Incomplete glottal closure of slightly irregular shape was observed (Fig. 6B). The left vocal fold vibrated along its whole length, and the frequency of vibration was irregular. The margins of the ventricular folds were sometimes observed to vibrate irregularly together with the vocal folds. The amplitudes of their vibration were small. The videokymographic image (Fig. 6C) substantiated and clarified the stroboscopic impression. It revealed clearly a double voice source with both ventricular folds (v) and vocal folds (f) vibrating. A relatively long vibratory cycle of approximately 11.5 ms was displayed, which corresponded to a frequency of approximately 87 Hz. Below the ventricular folds the vibrating left vocal fold (f) was visible. The ventricular folds closed maximally at the moment of maximal opening of the left vocal fold, reflecting the vocal fold–ventricular fold interaction during phonation. No signs of mucosal waves were seen in videokymography. These examinations led us to suspect tumor infiltration of the ventricular folds, which was later confirmed.

**DISCUSSION**

A comparison of the first results of videokymography with videolaryngostroboscopy shows that the videokymographic approach considerably enriches stroboscopy. Whereas many images are needed to evaluate the vibration pattern of the vocal folds produced by stroboscopy, videokymography is able to depict the pattern in one image. In this sense the method clarifies and adds precision to the stroboscopic results. Furthermore, it is no problem for videokymography to trace the vocal fold vibration even in cases of hoarse or breathy voices in which the stroboscopic method fails.
Data can be obtained from different points by evaluating the shape of the vibratory patterns, occurrence of mucosal waves on the vocal folds, and so forth. An important factor is the calculation and interpretation of the phase differences between the left and right vocal folds. Minimal differences between the left and right vibration patterns might help in future to explain the pathophysiologic mechanisms in voice disorders in more detail.

Videokymography may be used for evaluation and quantification of important parameters of the vocal fold vibration (asymmetry, periodicity, degree of glottal closure, speed quotient, as so forth) in a similar way as is done in high-speed imaging systems5,12,13 or in photokymography5,4. One has to keep in mind, however, that the vibratory pattern changes along the glottal length. This is strikingly visible in cases of organic pathologies, as was demonstrated here in the example of vocal fold polyp of patient 3 (OQ varied from approximately 0.2 to 1 depending on the measuring position). The same problem also appears, however, in normal vocal folds (Fig 2). Variation of the glottal quotients along the glottal length was observed in normal vocal fold vibration by Tanabe et al,13 and Gould14 in their classic high-speed cinematographic studies. Therefore, it is important to take the measuring position into account while evaluating the videokymographic findings.

The European television standard of PAL determines the duration of a video field to be 20 ms, of which 18.4 ms are used for image information. The remaining 1.6-ms interval is reserved for synchronization impulses necessary for television functioning and thus cannot contain any image information. Within the 18.4-ms time interval it is possible to make a detailed analysis of the course of displacement of the vocal folds during single vibratory cycles. This is advantageous for detailed evaluation of asymmetries, mucosal waves, and various glottal quotients. To investigate slight frequency disturbances in the voice, evaluation of longer time intervals is necessary, which might be done by analyzing vibratory patterns from more consecutive video fields. This was not done in this study, however. Further investigations using electroglottographic measurements, are planned in future.

CONCLUSION

Our results indicate that the videokymographic technique is a powerful tool that may contribute to deeper understanding of the mechanism of the vocal fold vibration. The combination of a relatively simple method for high-speed investigation of the vocal fold vibration, together with a technology that promises to not be excessively expensive, makes this technique promising for voice research, as well as clinical practice. It might be helpful in voice diagnostics (when used consciously) and also in voice therapy when monitoring of the pathologic, functional, and organic changes on the vocal folds is desirable.

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BIBLIOGRAPHY

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