Videokymography in 2000: the Present State and Perspectives of the High-Speed Line-Imaging Technique

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The paper provides an overview of the present state and perspectives of videokymography (VKG) in the field of voice research and phoniatrics and compares the advantages as well as disadvantages of the method with respect to the digital high-speed imaging systems. The (full) digital high-speed imaging systems are capable of providing more data on vocal-fold vibration than VKG, this advantage is, however, reflected in (ca. 5 times) higher costs of the system. Clinically oriented units as well as research laboratories with limited budget can benefit from using videokymography.

Keywords: videokymography, high-speed imaging, vocal-fold vibration

1 Introduction

Videokymography (VKG) was developed in 1994 in Groningen (NL) as a low-cost alternative of a high-speed imaging system especially suited for examination of vocal fold vibration. Since 1994 the system has encountered significant developments and in 1997 it became commercially available for public. The system uses a special CCD video camera which can work in two different modes – standard and high-speed. In the standard mode the VKG camera works as a standard commercial video camera with an image rate 50 (interlaced) fields/s in accordance with the CCIR TV standard. (Also NTSC video standard is available which provides the rate of 60 interlaced fields/s). In the high-speed mode, the camera delivers images from a single line (selected from the whole video field) at a rate of 7 812.5 line images/s. The consecutive line images are presented below each other on a monitor and create a new, VKG image which shows vibratory pattern of the selected part of the vocal folds. A more detailed description of the VKG principle was given elsewhere [1-3].

2 Differences between Videokymography and other Digital High-Speed Imaging Systems

The ability of providing both the standard as well as high-speed images of the vocal folds (between which the system can be immediately switched) distinguishes the VKG system from the (high-speed) linear cameras that are able to deliver only line-images. The two modes make the VKG system powerful and more practical for carrying out meaningful laryngeal examinations. In contrast to the high-speed digital imaging systems that provide full (laryngeal) images at high-speed, the high speed image rate is achieved at the expenses of reduced spatial information in videokymography. There are advantages as well as

disadvantages of the VKG approach when compared to (full-image) digital high-speed systems.

2.1 Advantages of Videokymography

The advantages of VKG in contrast to (full-image) high-speed systems may be listed as follows:

1) VKG is significantly less expensive (the equipment, as well as the storage costs per recorded time);
2) less amount of data have to be stored and processed.
3) the duration of the recording samples is virtually unlimited (especially when VCR and video tapes are used);
4) the format of the image information (CCIR or NTSC television standard) ensures that VKG works with standard, commercially available video equipment (standard video monitors, VCRs, etc.; generally the same video equipment as in videolaryngostroboscopy is used for VKG);
5) it offers an excellent spatial resolution (768 pixels/line in CCIR, c.f. usually 256 pixels/line is used in today's full-image high-speed systems);
6) it offers an excellent image rate (7812.5 images/s in CCIR; c.f. 1000 – 2000 images/s is the most frequently used rate in today's full-image high-speed systems);

2.2 Disadvantages of Videokymography

The disadvantages of VKG, as compared to the (full) high-speed imaging systems, arise mainly as a consequence of the fact that only a single image line is monitored in VKG. These are:

1) lack of the full image in the high-speed mode;
2) anterior-posterior phase differences in the vocal-fold vibration are not registered;
3) the measuring position has to be selected and properly adjusted before recording using the standard mode of the camera. (In the full-image digital high-speed imaging systems the place for a kymographic analysis can be selected after the recording was done [4;5]).
4) gross movements of the larynx could make the recording position inaccurate;

Certain disadvantages are related also to the use of the CCIR (or NTSC) TV standard:

5) VCRs and PCs often process and display two VKG images simultaneously, in an interlaced form (Figure 1);
6) the standard television format requires certain time interval within each video field to be reserved for synchronization purposes (ca. 2 ms per 20 ms in CCIR) and that interval cannot be used for the image information. These information gaps (see, e.g., Figure 2E) slightly complicate image analysis of longer passages of the resulting VKG signal.

2.3 Coping with the Disadvantages

Some of the disadvantages can be partially eliminated. In order to compensate for the lack of a full image (point 1), it appears useful to use VKG as a complementary method to videolaryngostroboscopy (see also section 3 below). Videolaryngostroboscopy provides full image of the vocal folds during vibration and may also reveal (at least qualitatively) anterior-posterior differences in the glottal vibration (point 2).

As far as the measurement position is concerned (points 3 and 4), it is recommended to employ the standard mode of the VKG system immediately before and immediately after the VKG examination. This makes it possible to confirm that the measurement position has not

changed during the VKG recording. Certain skill of the examiner is helpful for VKG, especially for the in-vivo laryngeal examinations. In order to eliminate the problem with displaying two VKG images simultaneously (point 5), it is desirable to utilize such a video system (VCR, PC software, etc.) which is capable of providing separate video fields instead of the interlaced frames.

The mentioned problems have been analyzed and technical improvements of the VKG system have been under investigation.

3 The Present State of Use of Videokymography

Videokymography has been employed in basic voice research as well as in clinical practice. In basic research, VKG has proven helpful in studying irregularities and sudden changes in vocal-fold vibration, including register transitions [6-8]. The high spatial resolution of VKG enables to measure relatively small displacements of the vocal folds which is advantageous, e.g., for observing the externally excited laryngeal vibrations and studying resonance characteristics of the vocal folds in vivo [9]. Also, information on the vocal-fold behavior during voice onset and voice termination can be obtained from VKG [10].

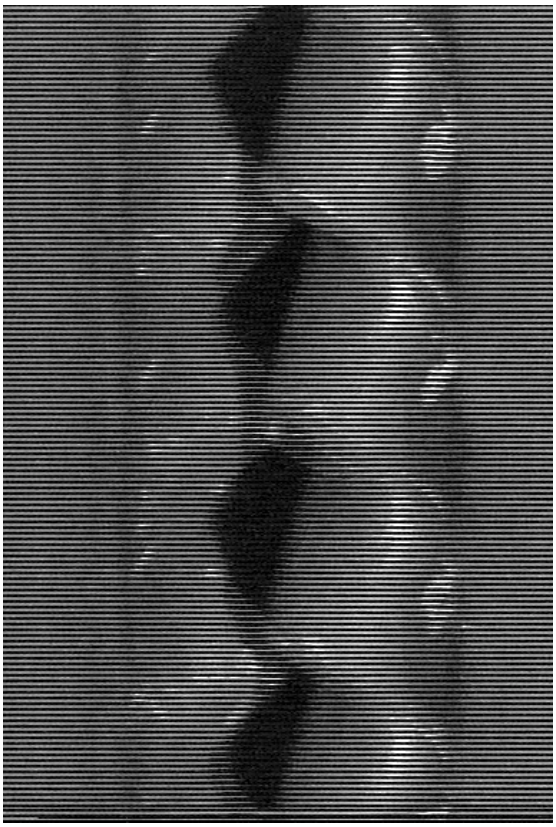

Figure 1. Standard video-imaging systems often display two VKG fields mixed in an interlaced form. For VKG purposes the two images should be separated. Figure 2D shows only one of the two images. Figure 2E shows both the images in the correct time sequence (3rd and 4th images from above in Figure 2E).

Clinical VKG examinations have established the value of the method as a complementary diagnostic tool to videolaryngostroboscopy. More than 1500 VKG examinations of patients with various voice disorders have been carried out in the Centre for Communication Disorders, Medical Healthcom in Prague. In order to provide the most comprehensive output, a method has been designed in which the VKG images are composed together with laryngostroboscopic images. In this way it is possible to objectively and effectively visually summarize important information on the properties of the vibrating laryngeal tissues [11-13] (Figure 2). Laryngostroboscopic images provide information on appearance and mobility of the laryngeal structures in breathing and during vibration and on that basis make it possible to qualitatively evaluate some of the vibratory features (regularity, shape of glottal closure, etc.). Videokymographic images complement stroboscopic findings in that they objectively reveal the dynamic behavior of the vocal folds in detail and they can be used for quantification of the vibratory parameters. The microdynamic characteristics of the vocal fold vibratory patterns as shown in the VKG signal, promise to enable a more objective ”dynamic diagnostics” of the voice disorders.

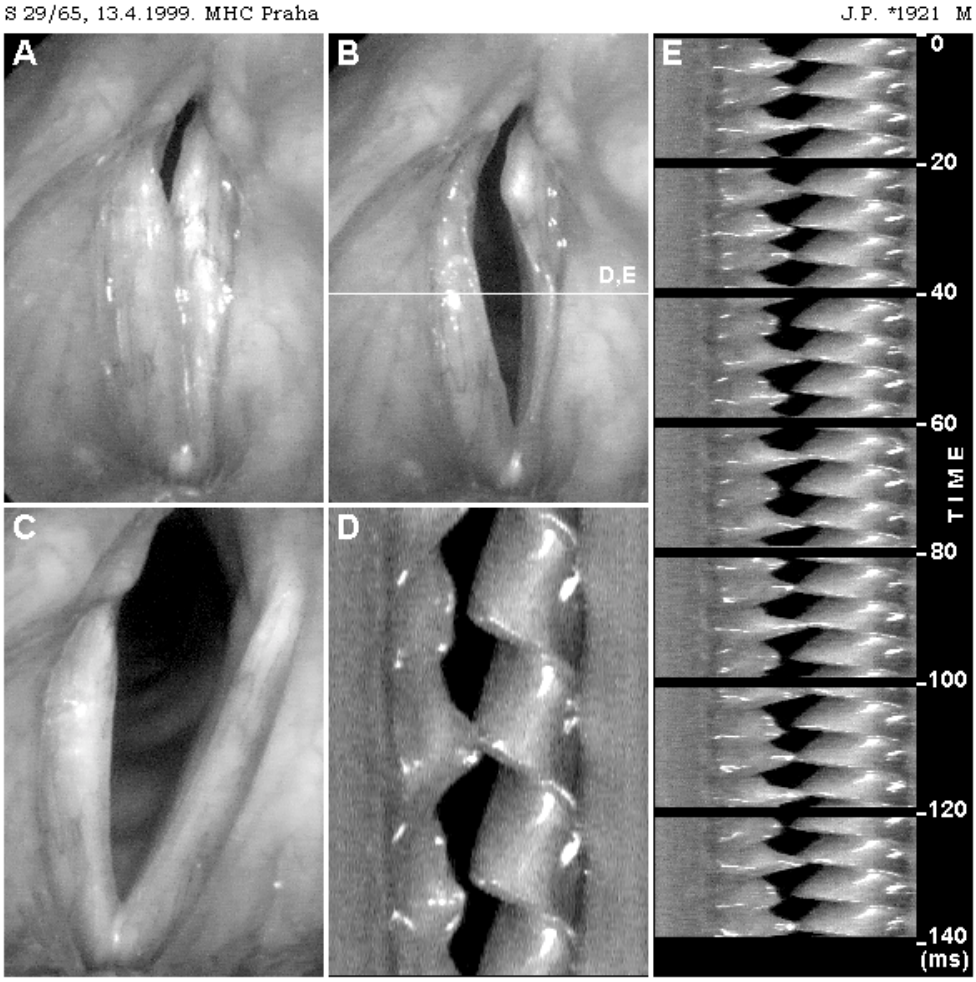

Figure 2: Male patient, age 78, suffering from vocal-fold paralysis right. Combination of laryngoscopic, laryngostroboscopic and videokymographic images makes it possible to effectively summarize relevant laryngeal findings. (A) laryngostroboscopic image at the phase of maximally closed glottis. A glottal gap remains in the posterior part. (B) laryngostroboscopic image at the phase of maximally open glottis. The horizontal line marks the recording position for the videokymographic images D and E. (C) vocal folds during breathing. The left vocal fold is fully abducted. The right, paralyzed vocal fold remains in the medial position. (D) Videokymography: single image revealing the vibration of the vocal folds in detail (total time displayed: ca 18 ms). Irregularities in the vibration are apparent especially on the right, paralyzed vocal fold. The irregularities are related to hoarseness of this patient. The left vocal fold shows strong mucosal waves which follow the opening movement and propagate laterally over the surface of the vocal fold. (E) Sequence of seven videokymographic images monitoring the vibration of the vocal folds during a time interval of 140 ms. The third VKG image (beginning at 40 ms) corresponds to the image D. (In all the images the left and right sides are reversed--it reflects the situation seen by the examiner when facing the examined subject).

4 Conclusion

The (full) digital high-speed imaging systems are capable of providing more data and more possibilities for analysis of the vocal-fold vibration than VKG, this advantage is, however, reflected in (ca. 5 times) higher costs of the system. Clinically oriented units as well as research laboratories with limited budget can highly benefit from using videokymography. It is advantageous to use videokymography as a complementary method to videolaryngostroboscopy. The (full) digital high-speed imaging system, on the other hand, appear to be most valuable for highly sophisticated research purposes.

References

[1] Švec JG, Schutte HK. Videokymography: high-speed line scanning of vocal fold vibration. J Voice, 10(2): 201-205, 1996.

[2] Schutte HK, Švec JG, Šram F. Videokymography: research and clinical issues. Log Phon Vocol, 22(4): 152-156, 1997.

[3] Švec JG, Schutte HK, Šram F. Introduction to videokymography. (Video tape). Prague: Medical Healthcom, 1997.

[4] Wittenberg T. Wissenbasierte Bewegungsanalyse von Stimmlippenschwingungen anhand digitaler Hochgeschwindigkeitsaufnahmen. (Dissertation). Aachen, Germany: Shaker Verlag, 1998.

[5] Larsson H, Hertegard S, Lindestad P-A, Hammarberg B. Vocal fold vibrations: high-speed video imaging, kymography and acoustic analysis. TMH-QPSR, 1-2/1999: 21-29, 1999.

[6] Švec JG, Šram F, Schutte HK, Miller DG. Bifurcations in the vocal fold vibration: laryngoscopic observations by means of videokymography. Presentation given at the 27th Annual Symposium: Care of the Professional Voice. Philadelphia, PA, June 1-6, 1998.

[7] Švec JG, Šram F, Schutte HK. Sudden changes in the vocal fold vibration: videokymographic observations. Presentation given at the PEVOC III, 3rd Pan European Voice Conference. Utrecht, the Netherlands, August 26-29, 1999.

[8] Verdonck-de Leeuw IM, Festen JM, Mahieu HF. Synchronized high speed videokymographic and acoustical recording of voicing. Presentation given at the PEVOC III, 3rd Pan European Voice Conference. Utrecht, the Netherlands, August 26-29, 1999.

[9] Švec JG, Horacek J, Šram F, Vesely J. Resonance properties of the vocal folds: in vivo laryngoscopic investigation of the externally excited laryngeal vibrations. J Acoust Soc Am (in review).

[10] Stelzig Y, Gall V, Cieslar-Rakus W. Die Kymografie im klinischen Einsatz und in der Stimmforschung. In: Gross M, editor. Aktuelle phoniatrisch-pädaudiologische Aspekte 1998/99. Band 6. Heidelberg: Median Verlag: 59-62, 1999.

[11] Schutte HK, Švec JG, Šram F. First results of clinical application of videokymography. Laryngoscope, 108(August):1206-1210, 1998.

[12] Šram F, Švec JG, Schutte HK. Possibilities for use of videokymography in laryngologic and phoniatric practice. In: Dejonckere PH, Peters HFM, editors. Communication and its disorders: a science in progress. Proceedings 24th Congress International Association of Logopedics and Phoniatrics, Amsterdam, the Netherlands, August 23-27, 1998. Vol. I. International Association of Logopedics and Phoniatrics: 256-259, 1999.

[13] Švec JG, Šram F, Schutte HK. Videokymografie: nova vysokofrekvencni metoda vysetrovani kmitu hlasivek. [Videokymography: a new high-speed method for the examination of vocal-fold vibrations]. Otorinolaryngol (Prague), 48(3):155-162, 1999.

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For more detailed information on videokymography see:

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