Chapter 9

A low cost high-speed camera system for vocal fold analyses

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Abstract

We describe here a less costly HSDI/HSDP system that can be constructed using commercially available components.

Keywords: *HSC, HSDC, HSDI, HSDP, stroboscopy, videostroboscopy, kymography, low cost system*

Introduction

Previously, high-speed cameras (HSC) utilized analogue technology and were used mainly for research purposes due to high costs and recordings drawbacks, while in the last 20 years a more user friendly high-speed digital cameras (HSDC) have been developed and applied to laryngeal analysis [1]. HSDC (b/w or color) allows instant digital slow motion control, digital storage on a normal video recording system and can deliver recordings with a frame rate of 2000 f/s, 4000 f/s, or even higher. These speeds are required to analyse high pitch phonation or study the mucosal wave, in singing [2]. Despite these advantages, most voice clinics continue to use stroboscopy rather than high speed digital imaging (HSDI) in daily clinical work. This is because videostroboscopy image quality is still of higher resolution than from HSC, the cost is less than the HSDI and processing is more user friendly. However, industrial HSDC are now becoming much cheaper than commercially available HSDI systems (KayPENTAX, Wolf) hence, we have adopted such an industrial camera system for larynx examination. We also developed a software adopted for simplified data processing.

The Hardware

The camera in question is HiSpec1 (Figure 1 A) from Fastec Imaging™ (San Diego, CA, USA). The camera is relatively small (65x65 mm) and of light weight (280 g) and gives a resolution of about 500x250 pixels with 4000 images/sec. Decreasing image size to 400x200 gives a speed of 6000 images/sec. This camera comes in two models, one monochrome and one color, but because of much higher light sensitivity we have chosen the monochrome for our system. The camera has a foot pedal for triggering. Sound is recorded with a microphone and an external soundcard. The system can be coupled to any fast type computer, but we use a Sony Vaio (Z11Z9) laptop model (See Figure 1 B). The light source is a 300 W xenon bulb from Wolf model 4447 (Richard Wolf, Knittingen, Germany). The system is normally used with any rigid laryngeal endoscope, but with good light source it is possible to use our system even with a flexible endoscope. Typically we use a 70 degree Stortz 8706 (Karl Stortz, Kreutzlingen, Germany) endoscope for transoral exam and a Machida ENT 30PIII (Machida, Tokyo, Japan) for transnasal visualization.

A B

Figure 1. Fastec HiSpec1 without (A) and with (B) laptop displaying a captured image.

The Software

The processing software developed by us is called High-Speed Studio (HSS). It facilitates recording and analyses. The software has a database for patient data and can collect information from integrated healthcare systems. The HSS allows for several types of analyses to be made. These include kymography [3], edge detection and sound synchronisation.

Database and software

The software program is a new version of high-speed toolbox [4] and is called High-Speed Studio (HSS), which is adopted for our camera system. For recording we use the standard recording program from Fastec Imaging™, where it is possible to set image size, recording speed, trigger mode, etc. The camera can set to a post trigger mode and can record continuously. When the foot pedal is pressed, the recording stops. From a trigger signal, the sound file can be synchronized to the images.

The HSS has a database entry to store patient name, ID, diagnose, recording date, file name, comments, and a quality index. The database has several search options: diagnosis, age, sex, etc.

The current cost for the B/W HiSpec1 camera is $18,000 and $8,000 for the High-Speed Studio software, excluding the cost for a PC/laptop and a 300 W light source.

Editors' Note: For current specs (March 2015) check *www.fastecimaging.com*.

Analysis

The recorded image sequence can be played continuously or stepwise, forward or backward. The sound can be played by pressing the sound button. Several tools are available for analyzing the recording.

Kymography is performed by placing a single mark line at any point across the image captured. Kymogram can calculate open and closing phase coefficients.

Another option is to track the glottal edges during vibration as shown in the Figure 2. This is accomplished by using "snake" algorithm and with a series of tests it is possible to automatically identify the vocal fold edges. When the edges are found it is possible to calculate the area of the glottis (GAW) in pixels. The GAW can then be presented as a graph and be compared to the sound signal.

A measuring stick can be used to calculate relative distance, angle, etc., between points of interest. If a distance is known, measure in absolute values are also possible.

Applications

The system described here has been used in our clinic since January 2011 and was so far used in examinations of over 2000 patients. Some types of phonations or dysphonic voices are especially useful to study with a HSDI as compared to traditional stroboscopy. This applies specifically to vibrations that are irregular, where mass differences between the vocal folds (VF) such as edemas, polyps or cysts are present, or when the difference in VF tension or elasticity (paresis, scarring). Another type of voice disorders which can be studied is VF tremor. Also, voice onset and very short phonations can also be analyzed with the HSDI as opposed to traditional video stroboscopy.

Results

In our voice clinic we routinely use video stroboscopy and now we also use HSDI, simply by using the same endoscope and changing the camera to HSDI system. This prolongs the examination by just a few minutes while gains are significant, especially in patients with irregular VF vibration.

Figure 2 shows normal VF vibration analyzed with our HSDI system. The software program allows analyses of detailed VF vibration over time by employing kymogram and edge detection. This allows us to analyze vocal fold movement of each VC.

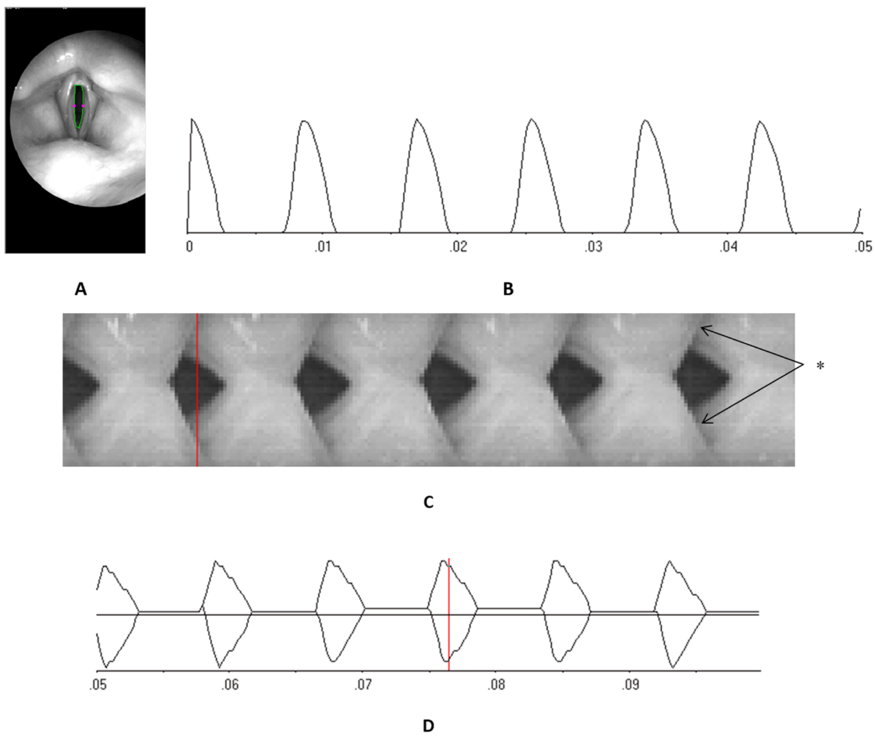

Figure 2. Normal VF vibration. A) Captured glottic image with edge detection area. Points show the position of point graph source (Fig 2D); B) Glotal area function in pixels; C) Kymograph of normal VF with corresponding L (bottom) and R VC activity per glottic cycle. Mucosal wave* is marked with arrows; and D) Point graph (see Fig. 2A) where the edge of the vibrating vocal fold can be followed separately, right vocal fold top, left vocal fold bottom.

Figure 3 shows irregular VF vibration in a patient with a discrete right VF sulcus. Both the kymogram and point graph shows phase delay at closure and decreased mucosal wave amplitude on right side. The point graph shows a plateau at maximal opening on the right side, indicating VF stiffness.

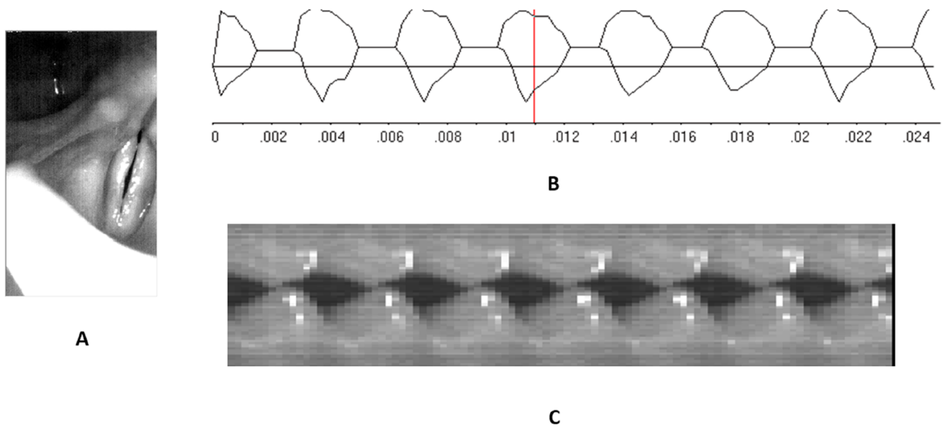

Figure 3. Irregular vibration. A) Irregular vocal fold vibration on a patient with discrete right vocal fold sulcus, filmed with 4000 f/s; B) Point graph analyses at the level of sulcus. Right vocal fold top, left vocal fold bottom, time scale in sec below; and C) Kymogram shows phase asymmetry at closure, decreased amplitude on the right side.

Discussion

The use of high speed filming gives a much better understanding of the work performed by VF especially when irregular vibrations are encountered and when examining dysphonia in singers. The use of the different tools in our system makes it possible to analyze VF vibration in details (See Figures 2, 3). The management of our HSS is very easy and flexible and the only equipment needed except the camera is a laptop and a light source. Hence, this system can easily be moved between different clinics. Moreover, the costs for our present HiSpec1/High-Speed Studio system is clearly lower than for other commercially available high-speed cameras.

The HSDI also has a didactic side by showing the examination to the patient. This makes it much easier for patients to understand the cause of their voice problem compared to presenting stroboscopic recordings only.

The optimal camera for larynx examination would be of course a very light sensitive color HSC, which can be used both in stroboscopic mode and high speed mode. So far we have not encountered such a camera, so the use of two cameras, one for ordinary video and one for the HSDI, during the same examination is a compromise awaiting advances in technology.

References

1. Imagawa, H., Kiritani, S., Hirose, H., 1987. High-speed digital image recording system for observing vocal fold vibration using an image sensor. Iyodenshi To Seitai Kogaku 25, 284-290.
2. Deliyski, D., et al., 2008. Clinical implementation of laryngeal high-speed videoendoscopy: Challenges and evolution. Folia Phoniatr. Logop. 60, 33-44.

3. Švec, J., Schutte, H., 1996. Videokymography: High-speed line scanning of vocal fold vibration. J. Voice 10, 201-205.
4. Larsson, H., Hertegård, S., Lindestad, P., Hammarberg, B., 2000. Vocal fold vibrations: High-speed imaging, kymography, and acoustic analysis: A preliminary report. Laryngoscope 110, 2117-2122.