ANALYSIS OF NORMAL AND PATHOLOGICAL VOCAL FOLD VIBRATION WITH REFERENCE TO VOICE QUALITY

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ABSTRACT

A digital image-recording system has been developed to facilitate high-speed image recording or vocal fold vibration using a tele-endoscope combined with a solid-state image sensor. The video signals are A/D converted and stored in the image memory together with acoustic signals. The system appears to be useful for the study of the relationship between vocal fold vibration and voice source characteristics in normal and pathological voices.

1. INTRODUCTION

Observation of vocal fold vibration is highly important for a study of the physiology and pathology of voice production. The analysis of vocal fold vibration has generally been performed by means of an ultra-high-speed movie system or a stroboscope. Although both systems have provided important data in the past, direct comparison between the image data and the acoustic signal has often been very difficult.

Recently, we developed a new method of digitally imaging vocal fold vibration using a solid-state image sensor attached to a conventional camera system. This system is relatively free from the mechanical noises and suitable for simultaneous recordings of voice signals and image data. Since the entire system is compact and easy to handle, the application for clinical use is promising [1, 2, 3].

2. METHOD

In the present system, a specially designed lateral-viewing laryngeal tele-endoscope is attached to a single-lens reflex camera. A MOS-type solid-state image sensor is attached to the back lid of the camera. The output video signals from the image sensor are fed into an image processor through a high-speed A/D converter. Stored images are then displayed on a CRT monitor. At present, frame rates of 2000/sec can be achieved with 100 x 36 picture elements. Simultaneous recordings of the vocal fold vibration and the voice signals have been performed for normal subject and pathological cases with different degree of hoarseness.

Figure 1 shows a block diagram of the system. The image memory has a 2-megabyte memory and a high-speed, 8-bit converter. As

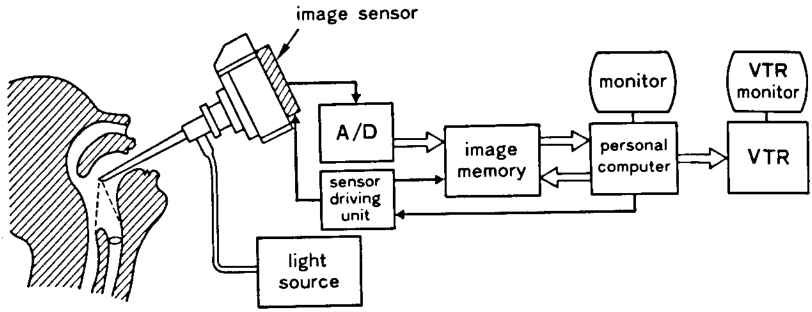


Fig. 1 Block diagram of the present system

a light source, a pair of 250 W halogen lamps are used.

Data recording is made in the same manner as in still photography of the larynx. The larynx is visualized through a view finder with the tip of the scope in the pharynx. The camera shutter is then released for data recordings. During the shutter opening of approximately 150 msec, 200 to 400 data frames are stored in the memory.

For the purpose of clinical application, recordings were made in those cases with organic changes in the vocal fold associated with "rough" quality of voice.

3. RESULTS AND COMMENTS

An application of the present system for the analysis of pathological larynx has proved promising. Incomplete glottal closure and asymmetrical or irregular vibratory patterns were easily identified in cases with recurrent laryngeal nerve paralysis, vocal fold polyp, polypoid vocal fold or sulcus vocalis. Furthermore, asynchronous movement patterns were often noted between the left and right vocal folds and/or between the anterior and posterior parts of the one vocal fold. It was also confirmed that, in most cases, pathological vibratory patterns were accompanied by irregularity in simultaneously recorded acoustic signals.

In the acoustic waveform, these voices show cycle to cycle variations in the waveform. However, in most cases, similar waveforms tend to recur cyclically (namely, at every other cycle, every third cycle etc.). Cyclic fluctuations in the pattern of vocal fold vibration are rather small and, in some cases, it is not easy to identify the pattern of fluctuation through simple visual inspection of the image.

In order to clarify the pattern of fluctuation in the movement of the vocal folds, brightness values at picture elements (pixels) along the horizontal scan line across the selected part of the glottis were plotted by the computer and characteristics of the successive frames were analyzed.

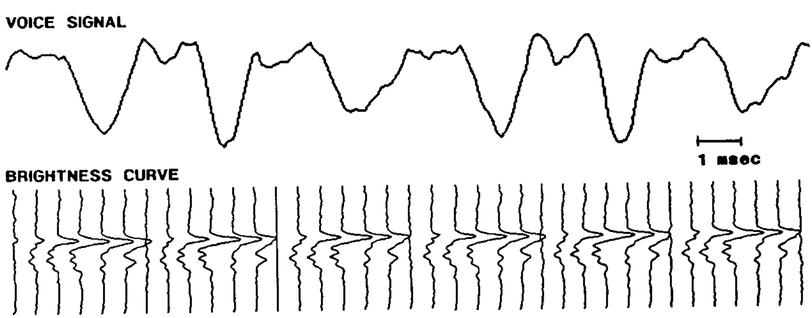
Figure 2 shows acoustic wave forms and brightness curves for Case 1, 20-year-old female with sulcus vocalis.

In this particular case, the right vocal fold showed only a very limited vibratory movement and a complete glottal closure was not obtained during the vibratory cycle. The acoustic signal shows three distinct cycles having different waveforms where a similar waveform appears at every third cycle. In one cycle, the dip in the brightness curve which corresponds to the glottal opening is clearly deeper than that in the other two cycles. The finding would indicate that the glottal opening is larger in that cycle than in the others.

Figure 3 shows acoustic waveforms and brightness curves for Case 2, a 59-year-old male with cyst of the left vocal fold. Observations of the vibratory pattern disclosed that the amplitude of vibration of the left vocal fold was much smaller than the right.

In this case, two distinct periods of strong and clear excitation and weak, noisy excitation alternated with each other resulting in fluctuation in the waveform at every other pitch period.

Inspection of the brightness curves indicates that the duration of the closure period is clearly different in these two cycles. In one cycle (cycle A, hereafter), the closure period is longer and the excitation in the speech waveform is strong. In the other cycle (cycle B), the closure period is short and speech waveform is noisy, suggesting that the glottal closure is incomplete in this cycle. In this particular case, it can also be noted that there is a marked asynchrony between the movements of the anterior and posterior parts of the glottis. In cycle A, the anterior part starts to open immediately after the posterior part closes, while in cycle B, the anterior part remains closed until after the posterior part begins to open. It can be speculated that this imbalance between the anterior and posterior parts of the glottis is



CASE 1 SULCUS VOCALIS

Fig. 2 A comparison between the acoustic waveform and the brightness curves for Case 1

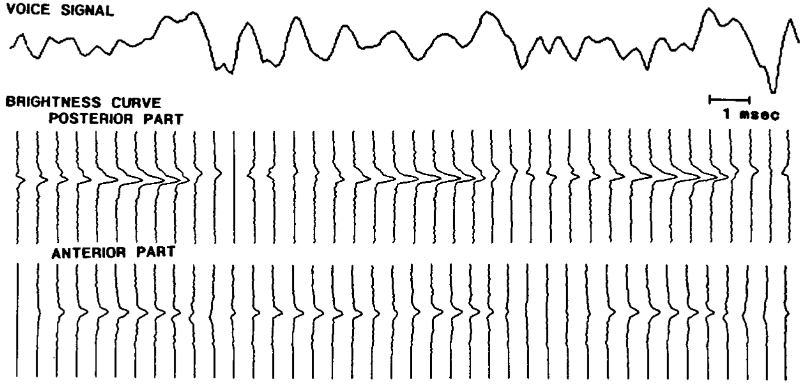


Fig. 3 A comparison between the acoustic waveform and the brightness curves for Case 2

related to the periodic fluctuation in the vibratory movement of the vocal folds.

The procedure for the recording and analysis of vocal fold vibration with the present system is simple compared to the conventional high-speed filming system. While the system is useful for practical purposes, a few technical improvements in the system's performance, particularly in the maximum frame rate, are still needed.

For clinical purposes, however, the present system has sufficient capability for the observation of pathological vibratory patterns and is useful as a practical unit.

It is thus expected that the present system would shed a new light for the understanding of physiological as well as pathological mechanisms of vocal fold vibration during voice production.

4. REFERENCES

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