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Observation of Pathological Vocal Fold Vibration Using a High-Speed Digital Image-Recording System

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Introduction

In order to facilitate high-speed image recording of vocal cord vibration, a new digital image-recording system has been developed at the authors' institute. The system employs a solid type endoscope combined with an image sensor. The video signals are A/D converted and stored in the image memory. Since the system does not have any mechanical unit producing noise, the simultaneous recording of vocal cord vibration and speech signal can be performed easily. The system is now being applied to a study of the relationship between vocal cord vibration and voice source characteristics in pathological voice. In the present report, preliminary results of an analysis of rough voice production are reported.

Method

The high-speed image recording system consists of an obliquely-angled solid endoscope combined with an image sensor. The output video signal from the image sensor is fed into the image processor through a high-speed A/D converter. Stored images are then displayed on a CRT monitor. A higher frame rate can be achieved by sampling only a limited number of picture elements in the image sensor. Frame rates of 2000/sec were achieved with 100X36 picture elements. The simultaneous recording of the vocal cord vibration and the speech signal was performed for a few patients with rough voice.

Results

Pathological vocal cord vibration in rough voices observed in the present study showed asymmetric movements between the left and right vocal folds. Furthermore, asynchronous movement patterns were identified between the left and right vocal folds and/or between the anterior and posterior part of the vocal folds. In the speech waveform, these voices show cycle to cycle variations in the waveform. However, in most cases, similar waveforms tend to recurr 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 images. In order to clarify the pattern of fluctuations in the movement of vocal folds, brightness values at pixels along the horizontal scan line across the selected part of the glottis were plotted by the computer and characteristics of the curves at successive frames were analyzed. Figure 1-3 shows glottal images, speech wave forms and brightness curves for three pathological cases.

Case 1 was a 20-year-old female with sulcus vocalis. In this case, the right vocal fold exhibited only a very small vibratory movement and thus, the glottal closure was not formed during vibration. The speech signal shows three distinct cycles having different waveforms. A similar waveform appears at every third cycle. Correspondingly, the brightness curves show similar patterns 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, indicating a larger glottal opening in that cycle.

Case 2 was a 59-year-old male with a cyst of the left vocal fold. The amplitude of the vibration of the left fold was much smaller than that of the right. In this case, two distinct periods of strong and clear excitation and weak noisy excitation alternated with each other, resulting in a fluctuation of the waveform at every other pitch period.

Inspection of the brightness curves shows that the duration of the closure period is clearly different in these two cycles. In one cycle (cycle A), 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 case, it can also be noted that there is a marked asynchrony between the movements of the posterior and anterior part of the glottis. In cycle A, the anterior part starts to open soon after the posterior part closes. On the other hand, in cycle B, the anterior part remains closed till after the posterior part begins to open. It can be speculated that this imbalance between the anterior and posterior parts of the vocal folds is related to the periodic fluctuation in the vibratory movement.

Case 3 was a 45-year-old female having a polyp. In this case, there is also an imbalance between the left and right vocal folds. The brightness curves show a smaller movement of the right vocal fold. The speech waveform shows an alternation of three different cycles. In one of these, the excitation pattern is not clear, and the waveform is noisy. The brightness curves reveal a corresponding cyclic variation.

The results of this preliminary analysis show that data recorded by the high-speed digital recording system are useful for investigating the relationship between pathological vocal cord vibrations and abnormal voice quality.

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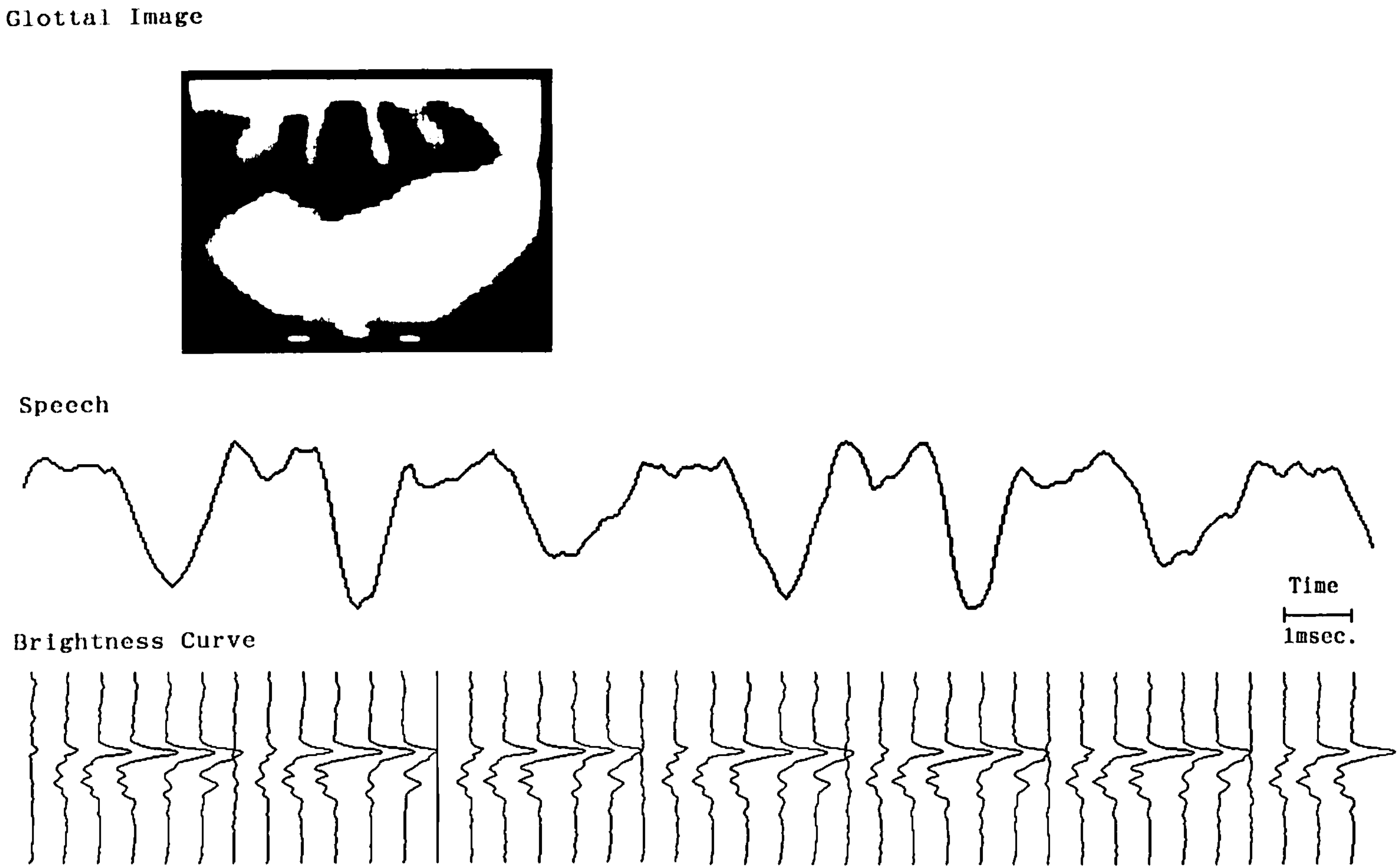

Figure 1. Case 1, sulcus vocalis.

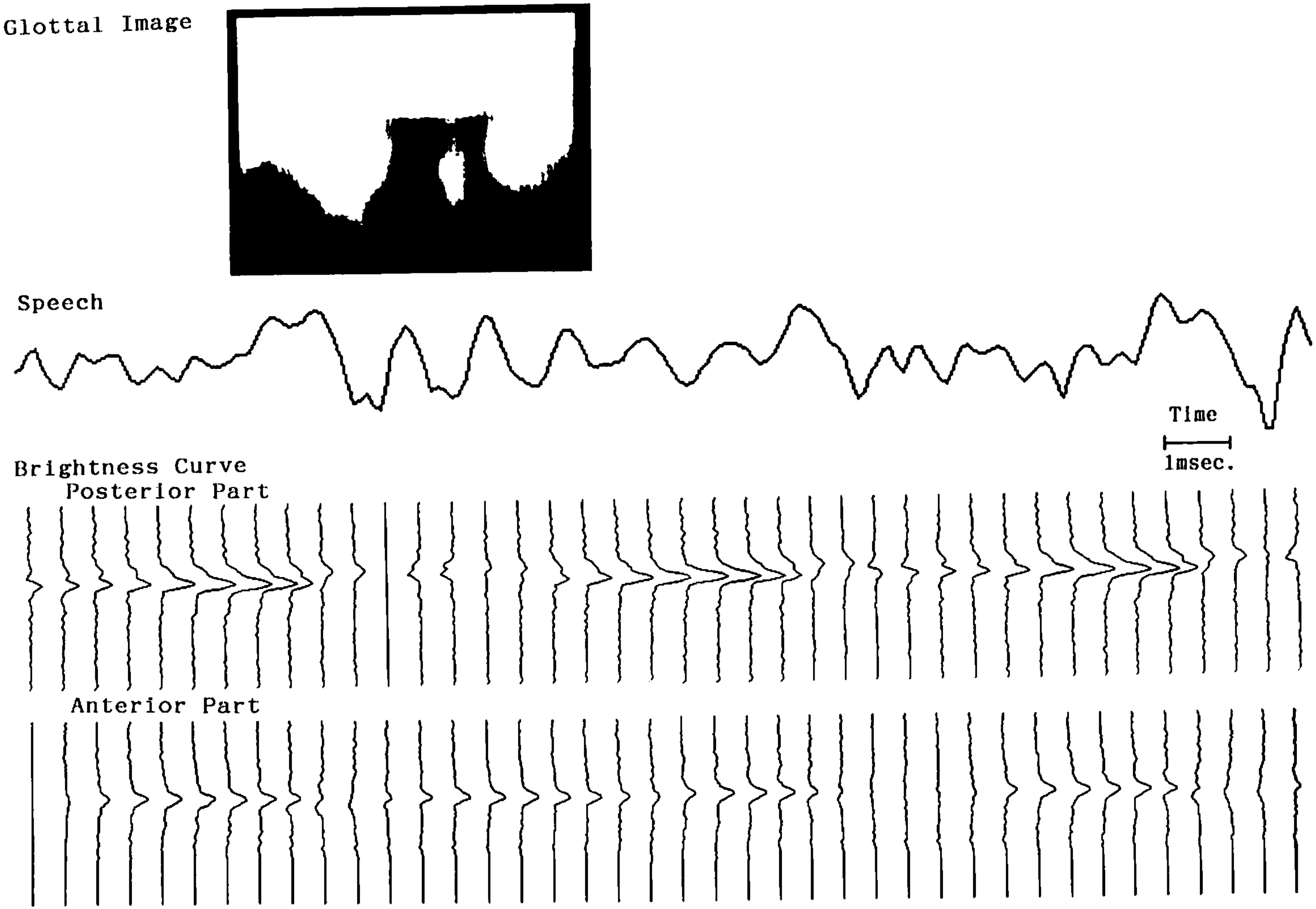

Figure 2. Case 2, vocal fold cyst.

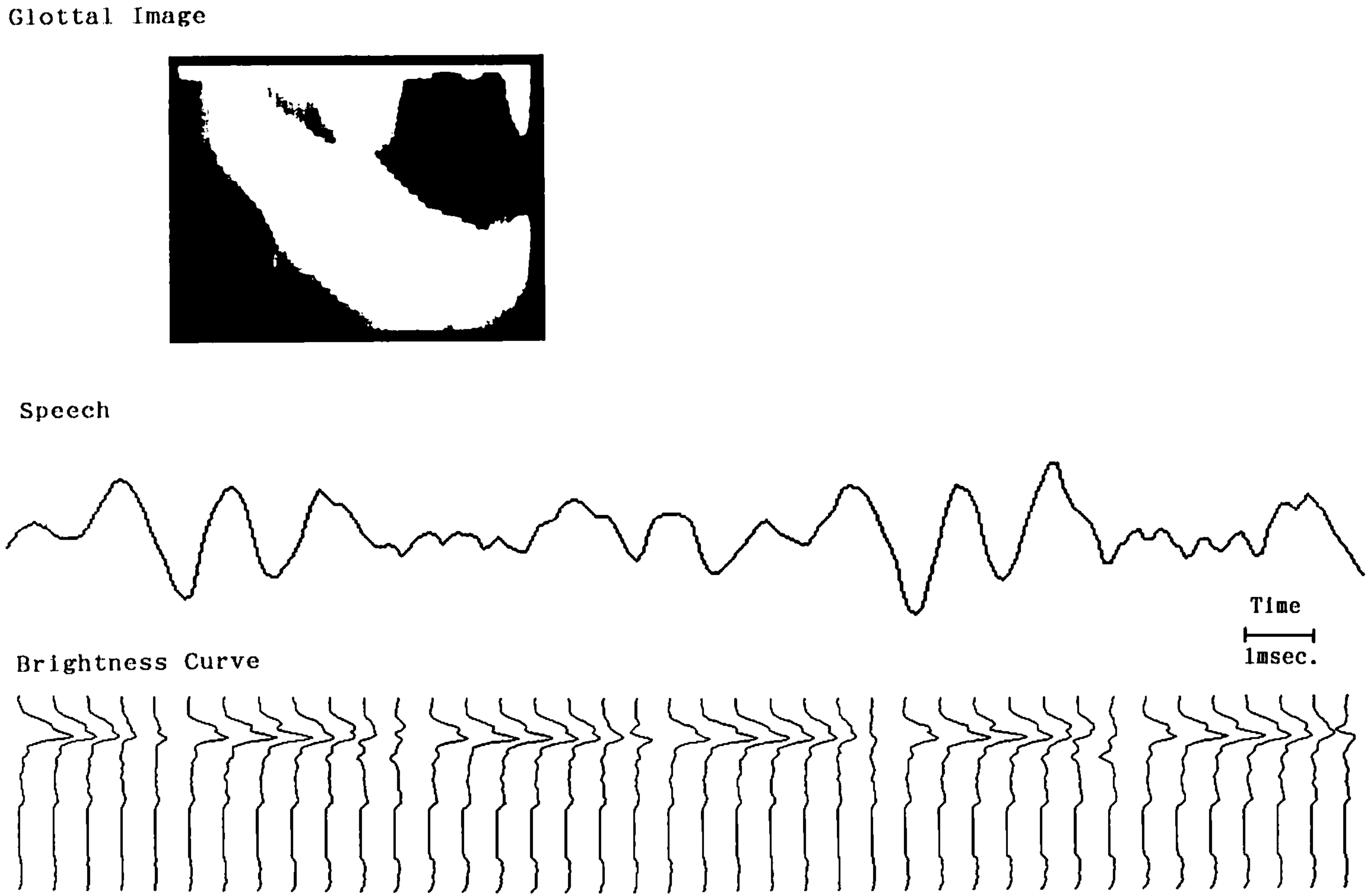

Figure 3. Case 3, polyp.