Proceedings of ITC-CSCC 2000, Pusan, Korea

Considerations on the Artifacts in a Cerebral Vascular Audiospectroscopy (CeVASS) using Spectral and Cross-Spectral Analysis

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Abstract— **The purposes of this paper are to clarify the influences of artifacts on a cerebrovascular audiospectroscopy (CeVASS) and to improve the detecting precision of the CeVASS. First, we perform the CeVASS in 15 healthy adults with various measuring positions such as forehead, eyes, cervical parts, temple parts, and occipitomastoid parts, and the influences of artifacts on each position is estimated. Next, we discuss about the removal of the artifacts using cross-spectral analysis. Finally, we propose an improved system of the CeVASS.**

I. BACKGROUND AND PURPOSE

It is important that early detection and early treatment of cerebrovascular diseases such as intracranial aneurysm, arteriovenous malformation (AVM), or vascular stenosis. In most of cases patients with the diseases have no subjective symptoms. These diseases may cause the patients either death or severe disability, if they become symptomatic. Therefore it is necessary that detection of the diseases in their early stages.

Several methods such as computed tomography (CT), magnetic resonance imaging (MRI), and angiography have been used for diagnosis of the diseases. These methods, however, are not appropriate for group examinations: CT method and MRI need very large equipment, and angiography is hazardous and painful. For these reasons, a simple and noninvasive method for detecting the diseases is required.

It has been known that the vascular diseases produce weak sounds which originate from the turbulent blood flow at the affected parts, and many studies have been done about the detection for which the sounds are used[1]–[7]. Kosugi *et al.* recorded the sounds with a pair of efficient detectors on the head surface and a special detector applicable to the tooth[3]. They detected sharp apexes in aneurysm patients and broad apexes in AVM patients. Sekhar *et al.* recorded the sounds with a horn-coupled probe microphone which was attached to its tip to fit over the eye[5]. They found a spike at certain frequency, a bruit over a band of frequencies, or a combination of the two. Kurokawa *et al.* used a laboratory-prototype transducer, which was placed on the unilateral eyelid, and detected sharp peaks in aneurysm patients and broad peaks in stenosis patients[7].

We proposed an audiospectroscopy (Cerebral Vascular Audiospectroscopy; CeVASS) for the detection with an accelerometer, previously[8]. However, it was difficult for this method to detect the weak sounds with high accuracy because artifacts such as ambient noises, heart sounds, and respiration sounds were mixed in the sounds. In this paper we investigate to the influences of such artifacts on the detection and attempt to improve the detecting precision of the CeVASS.

II. ARTIFACTS OF THE CEVASS

In the measurement of the blood flow sounds using the CeVASS, various artifacts cause decrease of the detecting precision. The blood flow sounds contain many components of the heart sounds, since the blood flow synchronizes with the heart. The respiration sounds are mixed in the blood flow sounds under the condition that the measuring positions are close to the mouth, the nose, or the respiratory tract of a subject. The ambient noises can be avoided easily with the help of a soundproof room. Then we investigate the influence of the heart and respiration sounds on the measurement, and attempt to remove the heart sound components from the blood flow sounds.

III. METHOD

A. Subjects and Measuring positions

We performed the CeVASS in 15 healthy adults in a soundproof room. Figure 1 shows the measuring positions of the blood flow sounds. These were the forehead (A, B), the eyes (C, D), the cervical parts (E, F), the temple parts (G, H), and the occipitomastoid parts (I, J) on the right and left of a subject. The heart sounds were also measured on the secondary intercostals sternum (K), and the respiration sounds were measured on the throat (L). The recording times were about 1 minute per measuring point. During the recording, the subjects were under the conditions of breathing and stop breathing.

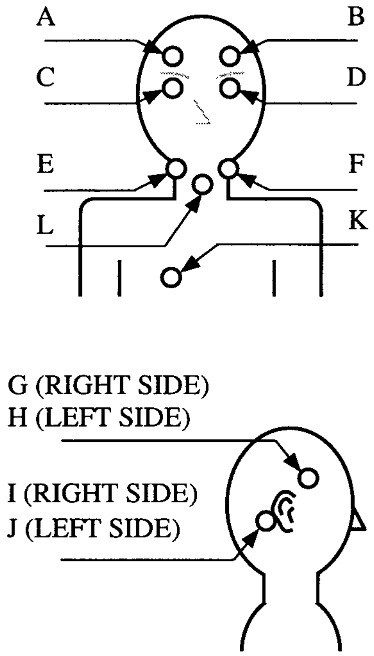

Fig. 1: Measuring positions.

B. Measurement of blood flow sounds

The block diagram of the measuring system is depicted in Fig. 2. The blood flow sounds were measured using accelerometers, which were fixed on each measuring point of a subject. The sound signals were band-pass filtered (200 Hz – 2 kHz), amplified, and sent to a digital data recorder at a rate of 10 kHz. The R-wave of the ECG was also inputted to the recorder as a trigger signal. In this recording the signals were truncated into 8192 samples from the peak of the R-wave. Figure 3 shows a sample of the truncated signal with the trigger signal.

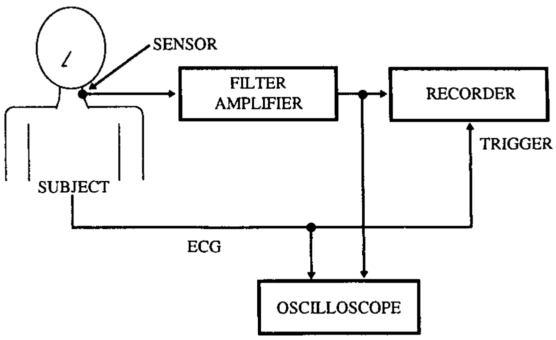

Fig. 2: Schematic diagram of the measuring system.

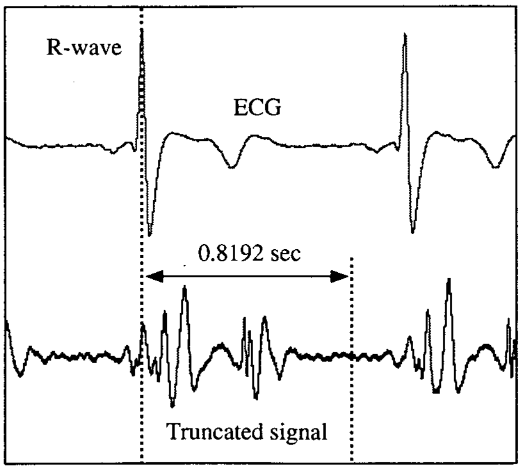

Fig. 3: Truncated signal with the trigger signal (R-wave).

C. Analysis

The recorded sound signals were sent to a computer. A fast Fourier transformation (FFT) procedure was performed on these data with a Hamming window function to obtain power spectra and cross-spectra of the signals. About 50 spectra were averaged into 1 spectrum to improve the signal to noise ratio for each subject in each measuring point. The spectra of 15 healthy adults were averaged into 1 spectrum, and were calculated the standard deviations in each measuring point. We calculated the coherence functions of the sounds by means of cross-spectral analysis between the signals at (A) to (H) and (K) where the heart sounds frequently affected, and (L) where the respiration sounds frequently affected. Moreover, we remove the heart sound components from the blood flow sounds of the positions (E) and (F).

IV. RESULTS

Figures 4 (a) to (c) show examples of the coherence functions which indicate the influence of the heart and respiration sounds in each measuring point. Figures 5 and 6 show the spectra of the healthy adults under the conditions of breathing and stop breathing, respectively. (a), (b), (c), (d), and (e) are correspond to the measuring positions (B), (D), (F), (H), and (J), respectively. The experiments about each measuring point yield the following results:

1) In the measurement at the position (B), the spectra of the blood flow sounds hardly had the influence from the heart and respiration sounds, and the standard deviations were very small in Fig. 5 (a) and Fig. 6 (a).
2) From comparison between Fig. 5 (b) and Fig. 6 (b), the spectra at the position (D) were influenced a little by the respiration sounds. The spectra also had the influence from the opthalmography.
3) The influence of the heart sounds appeared in the range 100 to 300 Hz in Fig. 4 (a), and the respiration sounds appeared in the range 100 to 800 Hz in Fig. 4 (b). Hence the spectra at the position (F) in Fig. 5 (c) had great influence from the heart and respiration sounds, and the standard deviations were large at 100 to 800 Hz.
4) The spectra at the position (H) in Fig. 5 (d) and Fig. 6 (d) had a little influence by the heart sound components, since the heart sounds appeared at 100 Hz in Fig. 4 (c). The standard deviations were small above 500 Hz.

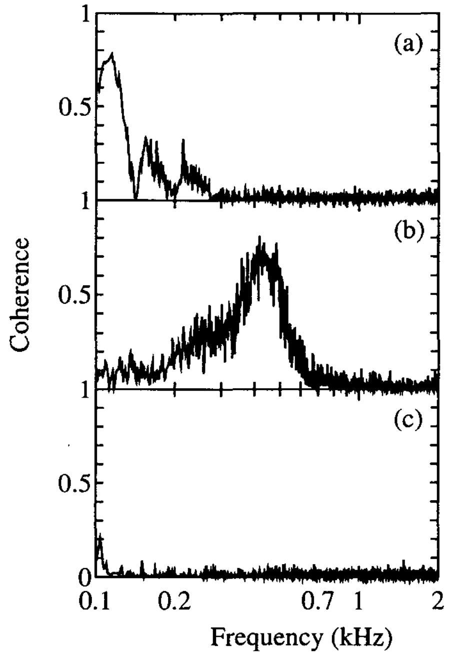

Fig. 4: The coherence functions. (a), (b), and (c) show the functions between the signals at (F) and (K), at (F) and (L), and at (H) and (K), respectively.

5) From comparison between Fig. 5 (e) and Fig. 6 (e), the spectra at the position (J) were influenced a little by the respiration sounds.

Figure 7 shows the coherence function between the signals at (F) and (K), which indicates the influence from the heart sounds. Figure 8 shows the spectrum which is removed the heart sound components from the spectrum at the position (F). The heart sound components were successfully removed from the spectrum at the position (F) in 100 to 200 Hz by means of cross-spectral analysis.

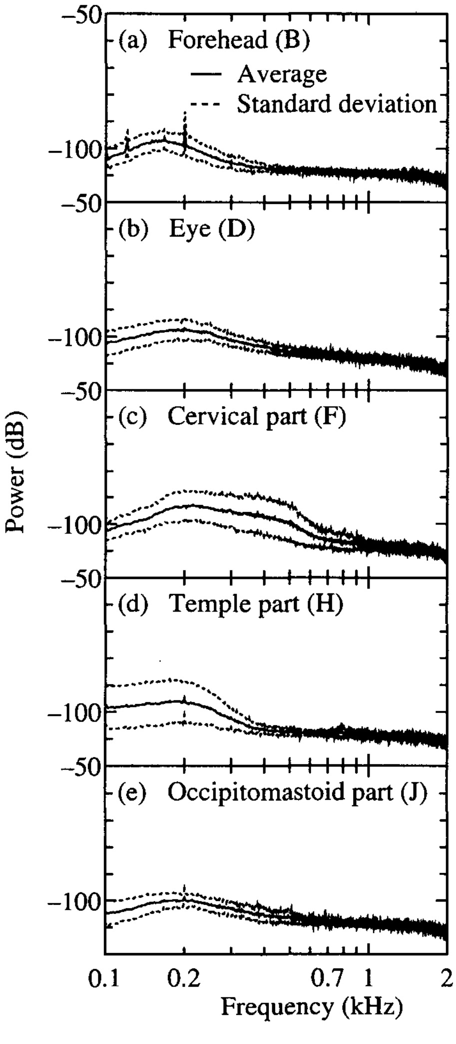

Fig. 5: Spectra of the healthy adults with breathing in each left side measuring point.

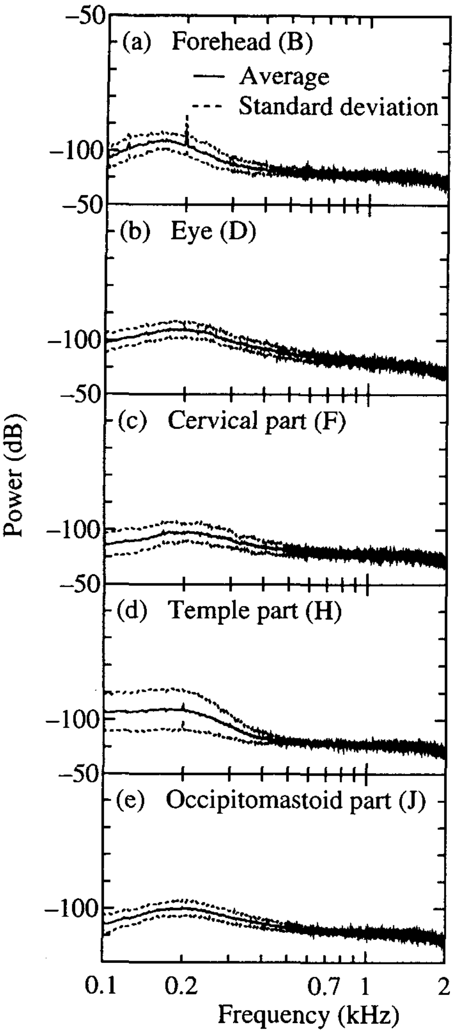

Fig. 6: Spectra of the healthy adults with stop breathing in each left side measuring point.

V. Conclusion

We have investigated the influences of the artifacts on the measurement of the CeVASS at various positions. As results, the sounds at the forehead (A, B) were hardly affected by the heart and respiration sounds, at the eyes (C, D) were affected by the opthalmography, at the cervical parts (E, F) were affected by the heart and respiration sounds, at the temple parts (G, H) were affected by the heart sounds, and at the occipitomastoid parts (I, J) were affected by the respiration sounds.

We have attempted to remove the heart sound components from the sounds at the cervical parts (E, F) using cross-spectral analysis. As a result, the heart sound components were successfully removed.

Consequently, it is possible to more improve the detecting precision of the CeVASS with the combination of some measuring positions at the same time.

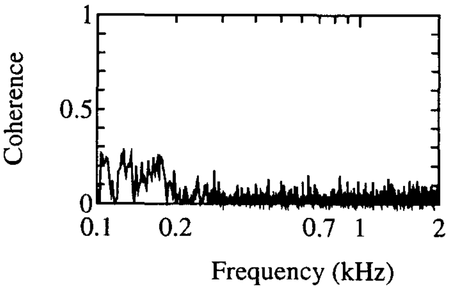

Fig. 7: The coherence function between the signals at (F) and (K).

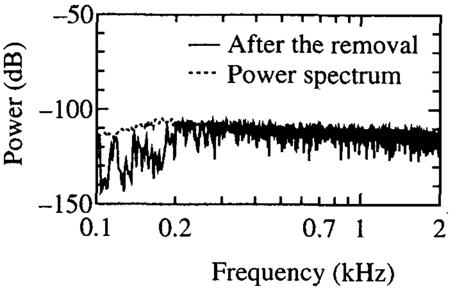

Fig. 8: The spectrum which is removed the heart sound components from the spectrum of (F).

Acknowledgments

The authors gratefully acknowledge the partial support of this work by a Grant-in-Aid from the Japanese Ministry of Education (No. 11671363).

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