Recording of the Fourth Heart Sound by the Signal Averaging Method

Preliminary Report

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SUMMARY

The fourth heart sound was clearly recorded by using the signal averaging method. Furthermore, the simultaneous recording of the Doppler signal with the fourth heart sound was performed. Thus, it was demonstrated that the Doppler signal started after the P wave and followed by the fourth heart sound. In 2 cases, the effect of the double Master's test and taking a bath was studied on the computer averaged phonocardiogram. After the exercise, the amplitude of the fourth heart sound was increased, whereas after taking a bath it was almost unchanged. The above results show that the simultaneous recording of a computer averaged phonocardiogram and Doppler signal that is associated with cardiac activity can greatly facilitate the interpretation of small vibrations such as the fourth heart sound.

Additional Indexing Words:
Apexcardiogram Doppler cardiogram Master's test Taking a bath

The fourth sound is usually small in amplitude and not always clear on an ordinary phonocardiogram. For a quantitative analysis, it is necessary to record the fourth heart sound with clarity. The simple use of greater amplification of the phonocardiographic signal will increase the noise. If there is no improvement in the signal-to-noise ratio, the fourth heart sound will remain unchanged. Recently, Berbari et al. used the signal averaging technique to detect the signals that are associated with the His-Purkinje system from the body surface in dogs. Using this technique, we have also succeeded in recording the His bundle potential from the body surface in man. We have also applied this technique for recording the fourth heart sound and

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succeeded in demonstrating it with clarity.

**METHOD**

The microphone (Model TA-50IT Nihon Kohden Co Ltd) was used for sensing the heart sounds. The microphone was attached to the chest wall with double-faced tape. Subjects were studied in the supine position. Placement of the microphone was uniformly in the fourth intercostal space immediately to the left sternal border. The lead II electrocardiogram was recorded with a time constant of 1.5 sec and simultaneous low frequency phonocardiogram was taken.

Fig. 1. The effect of the number averaged on the amplitude of the fourth heart sound. The number at the left of each panel shows the number averaged. V: vertical range; S4: fourth heart sound; PCG: phonocardiogram; ECG: electrocardiogram.

Fig. 2. The time relationship between the P wave, Doppler signal and fourth heart sound. DOP: Doppler cardiogram.
The signals obtained were passed to a signal averager (ATAC 1200 Nihon Kohden Co Ltd). The number of cardiac cycles averaged was about 50 or 100. For detecting the blood flow that is associated with cardiac activity a Doppler flow detector (DOPLETTE 10 Scientific Products Inc) was used. It consists of a transmitter which sends a high frequency sound wave (10 MHz) to a transducer. The signals were audible with a stethoscope earpiece attached to the DOPLETTE. These audible signals were recorded by using the microphone (RM-04 Rion Co Ltd). The fourth heart sound was recorded in 2 normal men before and after the Master’s test and taking a bath for 3 min at 42°C.

**RESULTS**

Fig. 1 shows the effect of the number averaged on the amplitude of the fourth heart sound. A progressive increase in amplitude of the fourth heart sound was observed by increasing the number averaged. Fig. 2 shows the time relationship between the P wave, Doppler signal and fourth heart sound. The Doppler signal occurred after the P wave and was followed by the fourth heart sound. An apexcardiogram recorded in the control condition is shown in Fig. 3. The A wave appeared slightly after the fourth heart sound. Figs. 4 and 5 show the effects of exercise and taking a bath on the fourth heart sound. After exercise, an increase in the amplitude of the first and fourth heart sounds was observed, whereas after taking a bath for 3 min at 42°C the amplitude

![Apexcardiogram](image-url)
was almost unchanged. As shown in Figs. 6 and 7, the Doppler cardiogram showed an increase in the early systole after exercise and an increase in early diastole after taking a bath. Figs. 8 and 9 show the left ventricular systolic time interval. The LVET/PEP was increased in both cases after exercise, whereas after taking a bath it was unchanged in one subject (Fig. 8) and increased in the other (Fig. 9).

**DISCUSSION**

Karpman et al\(^3\) have reported the signal averaging of the envelope of systolic murmurs and showed its clinical usefulness for the differential diagnosis of forms of pathological systolic murmurs. In this study the signal averaging method was used to detect the fourth heart sound. Recently, we have
Fig. 5. The effect of exercise and taking a bath on the fourth heart sound (Case 2).

demonstrated the similarity of the waveform recorded with the signal averaging method to that recorded with the intracardiac phonocardiographic method. Furthermore, we recorded the Doppler signal that is associated with cardiac activity. Thus, the time relationship between the P wave, Doppler signal and A wave of the apexcardiogram during the atrial activity was established.

Caulfield et al\textsuperscript{1)} have reported that in severe aortic stenosis a fourth heart sound is always present, but the presence of a fourth heart sound in adults with aortic stenosis implies severity of disease only in subjects under 40 years of age. It is generally known that the fourth heart sound is particularly increased in conditions of ventricular systolic overload such as pulmonary stenosis or pulmonary hypertension and aortic stenosis or systemic hypertension.\textsuperscript{5)} Bergman et al\textsuperscript{6)} have showed that the amplitude of the first heart
Fig. 6. The effect of exercise and taking a bath on the phonocardiogram and Doppler cardiogram (Case 1). The dotted line shows the tracing of the envelope of Doppler signal.

Fig. 7. The effect of exercise and taking a bath on the phonocardiogram and Doppler cardiogram (Case 2).

Fourth heart sound is easily measured and may provide a clinically useful method for evaluation of the left ventricular function and documentation of an abnormal left ventricular response to exercise stress. These studies show that the fourth heart sound as well as the first heart sound may provide a clinically useful
Fig. 8. The effect of exercise and taking a bath on the left ventricular systolic time interval (Case 1). Car: carotid pulse wave; RR: RR interval.

Fig. 9. The effect of exercise and taking a bath on the left ventricular systolic time interval (Case 2).
method for the evaluation of cardiac function. However, to relate the severity of these clinical conditions with the fourth heart sound, further study is necessary using the record of the phonocardiogram with improved fidelity. Our study shows that a computer averaged phonocardiogram and simultaneous recording of the Doppler signal that is associated with cardiac activity can greatly facilitate the interpretation of small vibrations such as the fourth heart sound.

REFERENCES