Portable Electro-Phonocardiograph Using Magnetic Tape Recorder Equipped with Patient’s Voice Print

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SUMMARY

A newly devised instrument is described which permits recording of cardiovascular sound and electrocardiogram during exercise in man. It consists of a handy magnetic cassette tape recorder and a modulator. This assembly is connected to a phonocardiographic microphone which is attached to the thorax with sticky tape. The voice of patient is also recordable, if necessary. Biological transducer will be attached for simultaneous recording. All of the recording will be inscribed on the oscillograph paper. It is demonstrated that the recording is stable even during exercise and represents satisfactory result. Prospect of this instrument is briefly discussed.

Additional Indexing Words:
Electrocardiography  Phonocardiography  Telemetering  Exercise

Recording of the phonocardiogram (PCG) during various procedures which modify the hemodynamic state has been drawn attention as a useful tool for the differential diagnosis of cardiovascular disease as well as for the estimation of diminished cardiac reserve.1) Most common technic is to record the PCG before and after physical exercise3,4,5) or under the effect of a certain drug. The latter has been more frequently used because of technical advantage in monitoring and recording the PCG continuously.5,6,7,8,9,10)

In order to record the PCG during exercise or routine activities, telemetering of the PCG has been attempted by several authors with unsatisfactory results due to technical difficulties.11,12) A portable tape recorder can be used more conveniently for this purpose with less restriction of patient’s activities. In our laboratory, a portable casette tape recorder has been developed for magnetic recording of the ECG.13) This report describes an extension of the technic to the simultaneous recording of the PCG and the ECG.14) In addition, the apparatus allows audible sound recording of patient's symptoms and other necessary comments in the same channel.
Methods

The apparatus consisted of a magnetic recording adaptor for the PCG and the ECG, a portable cassette tape recorder, a demodulator and a photographic recorder. A phonocardiographic microphone of air-conducting crystal type was designed as flat in shape and with lead wires from the narrow side for the convenience of applying to the precordium. The microphone was attached to the thorax with surgical tape Transpore®. A sound absorber was applied over the microphone, in order to reduce artefacts from the friction with clothes and from environmental noise. The location of the microphone on the thorax should be selected according to the patient examined. But the apex or the Erb’s area may be used for general purposes. The M filter for the PCG recording was arbitrarily selected (160 Hz/24 dB: tentative PCG standard in Japan).

Three different levels of sensitivity can be selected with 10 dB steps and fine

![Fig. 1A. Block diagram of modulation system.](image_url)

![Fig. 1B. Outlook of tape recording system.](image_url)
adjustment of ±5 dB is available for each step. The PCG amplifier and filters of different frequency response or with automatic level control can replace it, if necessary.

Small non-polarizable electrodes were attached to the precordium with surgical tape (Transpore®) for the ECG recording. Leads CM₅ and CC₅ were used mostly.¹⁵,¹⁶

PCG and ECG signals were recorded with frequency modulation by means of an astable multivibrator circuit. The central carrier frequency was 5.5 kHz for PCG and was 1.3 kHz for ECG. In addition, wow and flutter cancelling circuit with a phase shift oscillator was included in the magnetic recording adaptor (carrier frequency 3.0 kHz).

Three signals above-mentioned were recorded with a small cassette tape recorder in the same channel at the same time. Panasonic® RQ-210 model was used.
as a tape recorder. This model is small in size and is mechanically stable with minimal wow and flutter. Using a C-120 cassette tape, the continuous recording of one hour period is possible on one side of the tape. Fig. 1A shows the block diagram of the modulating system and Fig. 1B shows the apparatus.

On reproduction, ECG, PCG and wow and flutter cancelling signal were separated with band pass filters and then demodulated. Thus obtained ECG and PCG signals contain the fluctuation of the baseline due to wow and flutter of the tape recorder. Synthesizing wow and flutter cancelling signal and raw PCG and ECG signals with a differential amplifier, wow and flutter were cancelled and pure ECG and PCG signals could be obtained. Finally, the ECG and PCG signals were recorded with electromagnetic oscillograph with simultaneous monitoring with a speaker and a synchroscope. The block diagram of demodulation, monitoring and recording system is shown in Fig. 2A. Fig. 2B indicates the apparatus used.

The magnetic recording adaptor has a talk switch for the talking voice recording. With this switch on, talking voice is recorded through a small condenser microphone and the input for ECG and PCG is short circuited. Hence, the magnetic tape records only the voice and the carrier without modulation.

Fig. 3 A. Frequency response of PCG recording with modulation and demodulation.

Fig. 3 B. Frequency response of ECG recording with modulation and demodulation.
RESULTS

In order to improve the signal to noise ratio of the hard print, a high cut filter was used after the demodulation of the signals.\textsuperscript{17} The frequency characteristics of the PCG recording with modulation and demodulation processes are shown in Fig. 3A. Those of the ECG channel are shown in Fig. 3B. In modulating and demodulating processes, the input or output voltage and the carrier frequency changes must be linear. Modulation and demodulation characteristics of the PCG channel are shown in Figs. 4A and 4B, respectively.

![Fig. 4A. Frequency modulation characteristics of PCG channel.](image)

![Fig. 4B. Demodulation characteristics of PCG channel.](image)
Fig. 5 A. Frequency modulation characteristics of ECG channel.

Fig. 5 B. Demodulation characteristics of ECG channel.

Fig. 6. Frequency responses of the band pass filters.

\( f_1 \): ECG channel, carrier frequency 1.3 KHz,
\( f_2 \): W/F cancellation, carrier frequency 3.0 KHz,
\( f_3 \): PCG channel, carrier frequency 5.5 KHz.
Fig. 7 A. Recording sample. Normal male, 46 yrs old (C.S.).

Fig. 7 B. Recording sample. Tetralogy of Fallot. 12 yrs old male (T.H.).

Fig. 7 C. Recording sample. Aortic stenosis and insufficiency. 61 yrs old male (S.M.). ECG is distorted because of high voltage.
Those of the ECG channel are in Fig. 5A and 5B. The linear relation indicates no discernible distortion due to the processes. Another possible source of the signal distortion is frequency variations of the deep modulated signal. To eliminate this distortion, a certain band width must be allowed for the filters. Frequency characteristics of the band pass filters of our equipment are shown in Fig. 6.

Figs. 7A, 7B, and 7C are actual tracings from patients. With the use of wow and flutter cancelling circuits, the baseline shift of the tracings is minimal.

**DISCUSSION**

The function of the electronic circuits and mechanisms of our equipment was satisfactory and excellent results were obtained both for ECG and PCG, as long as the patient was in the resting state. During exercise, however, the ECG was stable enough but the PCG recordings were not perfect. This is partly due to an air-conducting crystal microphone, which is susceptible to the interference from the friction between clothes or from environmental noises. Similar difficulties have been mentioned by Furuya et al.\(^{11}\) in tele-metering of PCG as well. In spite of these artefacts in a part of the recording, as analysis of a long continuous record seems to provide satisfactory informations for most of the practical purposes.

Utilization of a contact type crystal microphone is in progress in our
laboratory. This type of microphone is much thinner and lighter, and is convenient for applying to the thorax. Moreover, a definite advantage is that it is less sensitive to the surrounding noise. It appears promising to use this type of microphone for the PCG recording during exercise (Fig. 8).

Since the PCG preamplifier and filters were inserted with plug-in type connection, other units containing compressor and automatic level control can readily be used, when the input of the PCG varies over a wide range (Fig. 8). Then, the level setting of the PCG amplifier can be omitted but the amplitude of the PCG tracing will not be linear to the input signal level.

Other applications of the apparatus include simultaneous recordings of other hemodynamic variables such as the plethysmogram by means of a biological transducer with a suitable preamplifier (Fig. 8). Or, the apparatus can be used as a 2 channel ECG, which can be combined to make a planer VCG loop.

A monaural casette tape recorder was used in this report, in order to make a portable and handy apparatus. When a stereo casette tape recorder will be likewise small and handy in the future, the cross modulation between channels can be reduced and the S/N ratio in the PCG recording will be improved. In addition, a multichannel apparatus will easily be constructed.

Combining the method described in this report with telemetering of PCG applications will be largely extended.

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References

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