Magnetorheography

Nonbleeding Measurement of Blood Flow in Man

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SUMMARY

A method was devised for measuring a blood flow signal from a body in intact state. When a body was placed in a high magnetic field, blood flow induced EMF was detected with surface electrodes using the same principle as an electromagnetic flowmeter. This method was named Magnetorheography (its recording: MRG).

This experiment was made on human subjects. The MRG from the wrist, chest and abdomen, was detected by this method.

Additional Indexing Words:

High magnetic field Surface electrode A-C amplifier Arterial
peak-to-peak flow Wrist Chest Abdomen

A method was devised to measure a blood flow signal from a body in intact state. When a body was placed in a high magnetic field, blood-flow-induced potentials were detected with surface electrodes by the same principle as for an electromagnetic flowmeter.¹⁾⁻³⁾ This method was named Magnetorheography; its recording, Magnetorheogram (MRG). A similar method using alternating magnetic field was reported.⁴⁾

The venous flow induced signal has frequency components sufficiently low to be considerably attenuated relative to the arterial flow signal. Therefore, only the peak-to-peak arterial flow signal can be measured out of the arterial and venous flow signals using an A-C amplifier which is incapable of measurement of very low frequency components and D-C.

In this study, the magnetorheographic measurement was performed on the wrist, chest, and abdomen in man. The MRG was detected with surface electrodes.

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METHOD

Two types of permanent magnets were used here. One is a small hoof shaped magnet which has a field intensity of 1 K gauss, a gap of 3.5 cm and a weight of 5 Kg. This was used for the experiments of the wrist. The other is a large magnet which has a field intensity of 7 K gauss, a gap of 25 cm and a weight of 5 ton. This was used for the experiments of the chest and abdomen.

The surface electrodes were affixed to the skin near the artery to be measured.

The blood flow signal detected with this electrodes, was fed to an A-C amplifier with a time constant of 1.5 sec.

EXPERIMENT ON HUMAN SUBJECT

Wrist

The wrist was placed in a gap of the small magnet. The surface electrodes were affixed to both radial and ulnar sides of the wrist, as shown in Fig. 1.

The MRG is shown in the upper panel of Fig. 2. To identify the MRG with blood flow signal, the wrist was suppressed with a cuff peripherally to the site of measurement. Greater part of deflections disappeared as shown in the lower panel of Fig. 2, but the motion artifacts of the electrodes remained regardless of the suppression. The results suggest that the greatest part of

Fig. 1. Recording of MRG from the wrist.

Fig. 2. MRG of control (upper panel) and in case of a suppression of the wrist peripherally to the site of measurement (lower panel). Lower tracing of each panel is ECG.

Fig. 3. Recording of MRG with a pair of surface electrodes affixed to the chest (b) and waist (c) of the body (a) in a high magnetic field.

MRG is related to arterial peak-to-peak flow as reported before.^{1),3)} The remaining deflections may also be due to the arterial flow and the motion artifacts.

Chest and Abdomen

The chest of a man was placed in a gap of the large magnet (Fig. 3a). The MRG was picked up by a pair of electrodes affixed to just below both nipples, as shown in Fig. 3b.

The recordings without a magnetic field, with a field of 7,000 gauss and an inversed field of 7,000 gauss are shown in Fig. 4. MRG is superimposed on the ECG in the magnetic field. On the MRG two significant peaks are observed between the S and the next T wave; the first peak was superimposed on the T wave while the other, on the end of the T wave. When the field

Fig. 4. The recordings of ECG and MRG from the chest. Calibration, 1 mV.

Fig. 5. The recordings of EMF and MRG from the abdomen. Calibration, 1 mV.

was reversed, they were also reversed. These results suggested that the first peak which is a positive deflection in a case of dorsofrontal field direction, corresponds to the ascending flow and the second peak which is a negative deflection in the same field direction, corresponds to the descending flow.^{1),3)}

The same experiment was made on the abdomen. When the abdomen was placed in the high magnetic field (Fig. 3a), MRG was detected with such surface electrodes as were affixed to both sides of the spinal cord in the waist, as shown in Fig. 3c.

Recordings without magnetic field, with a magnetic field of 7,000 gauss, and the reversed field of 7,000 gauss, are shown in Fig. 5. The MRG was superimposed on the ECG as in the case of the chest. In a dorsofrontal direction of the field, an upward deflection on the T wave was reversed when the field was reversed. These suggested that the deflection corresponds to the descending flow.

DISCUSSION

When a suppression of the wrist was made peripherally to the site of measurement, greater part of MRG disappeared (Fig. 2). The remaining deflections were probably due to the blood flow and the motion artifacts of the electrodes because the motion artifacts remained regardless of the suppression. These suggested that the greatest part of MRG of the wrist is related to the peak-to-peak flow of the radial and ulnar arteries (Fig. 2).

In the chest experiment there were 2 peaks on the MRG. The peaks were reversed when the field was reversed (Fig. 4). This suggested that they can be distinguished from the ECG and the noises of the electrodes. The first peak corresponding to the ascending flow, may, therefore, represent the flow of the ascending aorta because it bears some resemblance to the flow pattern of the ascending aorta. Likewise, the deflection corresponding to descending flow (Fig. 5) in the experiment of the abdomen was considered as flow patterns of the abdominal aorta. But further studies should be required to identify each MRG component with the corresponding blood flow.

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