The Study on Plethysmocardiography
A Preliminary Report

Hiroto MASHIBA, M.D.

An attempt to research mechanical events of the cardiac cycle, contraction and relaxation, not partially as roentgen-kymography or electro-kymography, but as a whole, was proceeded by application of principles of plethysmography and indirect roentgenography. An activating cardiac shadow on the fluorescent plate of fluoroscopy was converged on phototube by a lens. For diminishing the influence of intensity changes of X-ray beam, two phototubes were used in a balanced circuit. The difference of the phototube currents was practically entirely related to the absorption variations of the patient and fluctuation of the current was related mostly to the volume of the intracardiac blood. In this experiment, the curve obtained was analysed qualitatively. This new method to investigate the cardiac function, plethysmocardiography, is probably applicable to physiological and clinical examination.

Each method which has been used in the clinical determination of the function of the cardiovascular system possesses of its own significance and utility. The clinico-physiological studies of the heart consist of electrophysiology and hemodynamics, the former depends mainly, for its clinical significance, on electrocardiography which awaits further clinical interpretation and basic research, and the latter on intracardiac catheterization which invariably requires a surgical aid. The cardiac movements which are recorded by roentgen-kymography and electrokymography are only the partial movement of the heart. But the systolic movement converged, becoming intricately mixed oscillatory and rotatory movements, does not make sufficiently clear the dynamic phase of the heart beat. The mechanical movement and the hemodynamics of the heart and the relation between the cardiac movement and the peripheral circulatory condition can hardly be explained without the information to be gained by recording continuously the manner of the whole cardiac work in its systole and diastole.

Method

Fig. 1 illustrates the principles on which the cardiometrical method is based and the apparatuses used*; current A-B flows continuously and in an invariable

From the First Department of Medicine (Director: Prof. K. YAMAOKA), Faculty of Medicine, Kyushu University, Fukuoka.

* The apparatus used: an X-ray generator (Polydor, Siemens), a roentgen tube (F.D.O.-63, 392
amount through the phototube P-1, which received on the fluorescent paper pasted on it, the X-ray entering it directly from the X-ray tube; the fluorescent plate is quite dark and admits a decreased current B-C or is bright and admits an increased current B-D, according to the dilatation of the heart being filled with blood or to the contraction of the heart leaving little blood in it. When P-1 and P-2 are connected as in Fig. 1, current B-C is equal in volume to the X-ray absorbed by the chest wall, lungs, mediastinal cavity and by the wall of the heart; the current changing in amount in relation to this invariable amount of the X-ray undergoes another quantitative change as the blood in the heart and the great vessels fluctuates in volume, and current C-D shows the cardiac output. This current changing in value, when amplified and recorded, forms a curve to be described later.

The shadow cast by the heart on the central part of the fluorescent screen undergoes some change in size as the heart beats, which, depending on the amount of the X-ray reaching the screen, is composed of not only a change in shape on the frontal surface but also a change in thickness on the sagittal surface. The change in the amount of the X-ray reaching the screen is ascribable mainly to the change that the heart produces as it contracts and dilatates in the volume of blood existing in the heart and the major vessels. Accordingly, the current into which the changing brightness of the screen is converted in a phototube, when determined in a galvanometer, amplified and recorded, denotes the change occurring in the amount of blood contained at the same time in the heart and the great vessels.

The cardiometry, which is based on indirect roentgenography and electrokymography and by which the change occurring in the volume of the heart is graphically traced, led to the result described below.

Toshiba), a fluorescent plate (F. 4, Kyokko), a converging lens (Canon F-1.8, f-35 mm.), phototubes (P-1; RCA 931-A, P-2; RCA 1P21), and amplifier and resister (Electrokymograph, Mingograph-42, Elema).
RESULT

Fig. 2 is from a normal person, a 24-year-old healthy female, with no detectable vascular abnormality. Two curves from the subject, one (above) E.C.G. (lead–II) and the other (below) tracing the heart volume, appeared at the same time. The appearance of the P-wave and of the QRS-complex was followed by that of the waves tracing the ventricular contractions, the latter waves were similar in form to those tracing the changing volumes from the dog ventricle\(^1\) and normal ventricular curve of an electrokymogram,\(^2\) and the T-wave terminated when each ventricular contraction had reached its acme.

![Fig. 2. A normal case.](image)

Fig. 3 is from a patient with a cardiac disorder, a 26-year-old female, with clinical symptoms of mitral stenosis and regurgitation. The heart action was traceable from E.C.G. (lead–II). Two traceable ventricular extrasystoles, which occurred in no time to a normal ventricular contraction, had a prolonged systole occurring between normal contractions. Another ventricular contraction traced from this patient reached its acme sooner than a corresponding contraction from a normal person.

![Fig. 3. A Patient with mitral stenosis and regurgitation.](image)

Fig. 4 is a tracing from a 22-year-old female, in whom an intracardiac
catheterization confirmed the presence of patent ductus arteriosus. E.C.G. of lead II revealed no abnormality in this patient but the heart volume traced simultaneously showed that a small characteristic contraction presumably indicates the contraction and dilatation of the major vessels and appeared between the middle of a normal systole and the end of an accessory normal diastole, i.e. before the appearance of a P-wave.

![Fig. 4. A patient with patent ductus arteriosus.](image)

**DISCUSSION**

Approximately 160 ml. of blood sent out and taken in each cardiac cycle by the heart is naturally accompanied by corresponding variation in the amount of the X-ray to be absorbed within a human body under X-ray examination and by a consequent variation in the brightness of the fluorescent plate. This variation, recorded continuously for a certain period, may reasonably be expected to serve as a valuable metrical means of medical research. E.C.G. from a normal person gave as a whole a satisfactory record of the ventricular systole bearing a particular resemblance to the electrokymographic record of the same movement. As may naturally be expected a small-sized wave appearing in the record of each systole was unanalysable but the arterial and venous activity was a probable factor in its appearance. Calibration of voltage remained as another unsolved problem, and the cardiac output, an important problem in its own way, was left unexamined in this experiment, as mentioned in the beginning of this paper. The changing volume of the first case was examined with a view to observe the waves tracing extrasystoles. The result reached gave a key to the quantitative analysis of such waves and made it possible to determine without the aid of E.C.G. extrasystole, atrial fibrillation and the coincidental dynamic phase of the blood in circulation. The changing heart volume in the second case was examined to evaluate the diagnostic value of the present method. It was found as a result that a small characteristic wave tracing a systole and appearing between a T-wave and a P-wave was of high clinical significance, provided it was invariably traceable from a patient with patent ductus arteriosus. Two technical problems awaiting
further investigation are how to adjust the calibration voltage and how a wave-length specific to the fluorescent plate is related to a wave-length specific to the phototube. The dynamic phase of the blood supplying the head and the extremities which was considered in this experiment, will also be applied for diagnostic purpose.

It is the author's intention to examine this method in more detail for its improvement.

**Summary**

(1) A new method by which the changing volume of the heart can be recorded was devised for continuous observation of the heart as a whole.

(2) The principle on which the method is based was explained and the apparatuses used were described.

(3) The auricular and ventricular contractions in a normal case were accurately traceable by this method.

(4) Extrasystoles in a patient with mitral stenosis and insufficiency were recorded as corresponding abnormal contraction.

(5) Peculiar waves probably indicative of contraction of the major vessels, were recorded from a patient with patent ductus arteriosus.

(6) The experimental and diagnostic significance of this method seems to be nearly settled by the above described informations obtained by it.

(7) More detailed examination of this method and its improvement are being attempted.

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**References**
