INVESTIGATION OF THE ELECTRIC FIELD OF THE ISOLATED DOG'S HEART

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A method of investigating the electric field of the isolated perfused animal's heart in a liquid volume conductor is described. Potentials are recorded from 241 points on a spherical surface surrounding the heart by a unipolar technique. The electrodes are 1-2 cm away from the surface of the heart. The leads are grouped together 6 at a time. One of them is recorded as a constituent of all groups and serves for synchronization. The method is intended for the study of various types of equivalent electrical generators of the heart.

KEY WORDS: electrocardiography; electric field of the heart.

Modern electrocardiography is based on determination of the parameters of the heart as an electric generator by measuring the distribution of potentials of the body surface. However, because of the extreme complexity of the actual cardiac generator it is not always possible to determine its characteristics exactly. The urge to make electrocardiography a quantitative method of investigation has therefore led to the creation of simplified mathematical models, known as equivalent electric generators of the heart [1]. One such model that has received the closest study is the multipolar equivalent generator [2].

In order to choose the optimal equivalent generator, the potentials of the electric field of the heart must be accurately and completely measured. Attempts to do this in studies on man have met with considerable difficulty because of the nonhomogeneity of the electrical properties of the body, the complex geometry of its surface, and the need for synchronized recording of the potentials at very many points. These difficulties can be overcome by studying the electric field of the isolated heart of an experimental animal [3].

This paper describes a method developed for the investigation of the electric field of the isolated heart, with the particular aim of studying different models of the equivalent generator.

EXPERIMENTAL METHOD AND RESULTS

The isolated dog's heart, perfused with a stabilized donor's circulation, was placed in a cubical plastic vessel about 30 liters in volume. The vessel was filled with physiological saline (a volume conductor) at a temperature of 38°C.

The scheme of measurement is shown in Fig. 1. The apparatus consists of 2 identical rings, made from insulating material, rigidly fixed together at the upper and lower poles and lying in two mutually perpendicular meridional planes. The isolated heart is placed inside the rings, with its geometric center as close as possible to the center of the sphere formed by the rings. The direction of the longitudinal axis of the heart is arranged to be as near vertical as possible. By means of a special device the contracting heart is kept in this position throughout the experiment. The construction described can rotate around a

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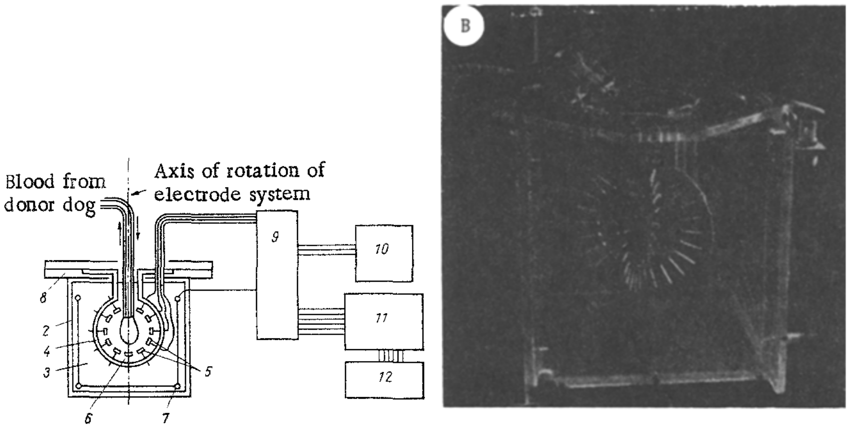

Fig. 1. Experimental apparatus for investigating the electric field of the isolated dog's heart: A) block diagram of the apparatus: 1) isolated perfused heart; 2) cubical plastic vessel; 3) physiological saline (volume conductor); 4) ring with recording electrodes fixed to it; 5) recording electrodes; 6) recording electrode of standard lead; 7) electrodes of "zero terminal"; 8) mechanism for rotating the system of electrodes around the heart; 9) commutator for the leads; 10) electrocardioscope; 11) 6-channel biopotentials amplifier; 12) loop oscillograph. B) external appearance of the system of recording electrodes.

vertical axis (around the heart). On each ring there are 20 silver recording electrodes, 5 mm in diameter, fixed to the ends of thin plastic tubes arranged radially toward the center of the sphere with electrodes facing the surface of the heart. The angle between adjacent electrodes on the ring is 15°. The distance of the electrodes from the heart surface can be varied. One additional electrode is placed on the lower point of intersection of the rings. Its position remains unchanged however the system is turned, and the signal recorded from it can therefore be used as a reference for synchronization of the signals from all the other leads. Potentials recorded by the electrodes were measured by a unipolar technique relative to the potential of the "zero terminal" formed by 8 interconnected electrodes. These electrodes were located in the corners of the vessel, at the points farthest away from the heart.

To obtain a detailed picture of the distribution of potentials, recordings must be taken from as many points as possible of a volume conductor. For this purpose the construction described above, consisting of 2 rings with electrodes fixed to them, was rotated before each successive stage of the measurements around a vertical axis (i.e., around the heart) by an angle of 15° – a total of 90° for the complete experiment. In this way it was possible to obtain 241 recordings from points uniformly distributed over a sphere around the heart and 1-2 cm away from it.

The potentials recorded were amplified with a 6-channel amplifier and recorded on a loop oscillograph. Since an essential condition of measurement was the simultaneous analysis of all the curves recorded, one recording channel was always used for a reference synchronizing lead and the other 5 channels were connected in turn to all the other recording electrodes. Visual control of the records was supplied by the 3-channel VÉKS-4 electrocardioscope. The duration of all measurements was 20-25 min. For the subsequent analysis experiments were chosen in which no marked changes were observed in the state of the heart during recording. To correlate the results of the measurements with the spatial distribution of excitation in the heart, the heart was always placed in the same position.

To present the curves in numerical form, the amplitudes of the curves (in mV) at consecutive time points at intervals of 4 msec were measured in a region of the QRS complex about 60 msec in duration. The consecutively recorded curves were synchronized with the aid of the reference signal. As a result values were obtained for the potential of the electric field of the heart on a spherical surface around the heart at successive moments during the period of ventricular depolarization.

Equipotential maps of the distribution of potential of the electric field of the heart for 3 moments of time corresponding to the beginning, middle, and end of the QRS complex are illustrated in Fig. 2. The first map corresponds to the time when excitation covers the ventricular septum and the subendocardial regions of the ventricles. A number of extrema can be seen on the map, from which it follows that the

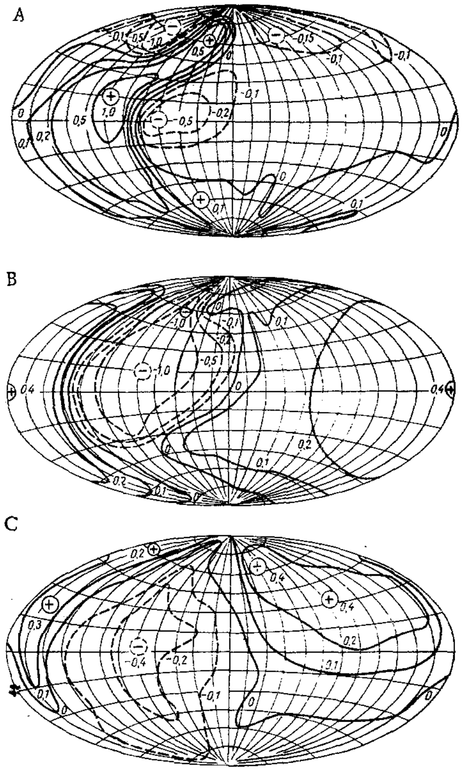

Fig. 2. Equipotential maps of distribution of potentials in a volume conductor on a spherical surface around the heart: A) 12 msec after the beginning of the QRS complex; B) in the middle part of the QRS complex (28 msec); C) 44 msec after the beginning of the QRS complex. Orientation of the heart relative to the equipotential maps: upper – base of the heart; lower pole – apex of the heart; to the left of the vertical line – right ventricle; to the right of the vertical line – left ventricle.

cardiac generator at a given moment of time has a complex and evidently nondipole structure. The second and third maps correspond to the spread of excitation into the substance of the ventricular myocardium. The distribution of potentials on these maps is more "dipole" in character.

The results of these measurements can be used to calculate the parameters of the equivalent generators of the heart of any given structure, limited only by the degree of error of describing the cardiac field associated with this method.

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