Effect of Torso Shape and Heart Location in the Chest on Formation of Cardiac Electric Potentials on Body Surface in Dogs

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Experimental and theoretical methods were employed to study the effects of torso shape and heart orientation in the thoracic cavity on peculiarities of the formation cardiac electric field on the body surface in dogs. It was found that heart orientation to a greater extent than torso shape affected projections of cardiac electric potentials from the epicardium onto the body surface.

Key Words: *extracardiac factors; cardiac electric field*

The torso shape and orientation of the heart determine the spatial relationships between electrical potentials in the heart and those led from the body surface. The effects of body shape and heart orientation in the thoracic cavity on the cardiac electric field (CEF) measured on the torso surface are mainly studied on humans [1-3,5].

Our aim was to study the effects of torso shape and heart orientation on CEF distribution across the surface of canine torso.

MATERIALS AND METHODS

In random-bred dogs (n=10) narcotized with sodium thiopental electric potentials of CEF were recorded in a supine position using a 128-channel setup. Surface unipolar ECG were synchronously recorded with 64 electrodes, thereafter the thorax was opened, and similar recording was performed with 64 electrodes placed onto the ventricular epicardium. The CEF data obtained form the body surface and the epicardium were synchronized with ECG led from forelegs.

Geometrical measurements were used to simulate the cardiac and body surfaces of individual dogs (Fig. 1). The projections of epicardial potentials onto the body surface was examined with mathematical model [4], which was a system of linear equations that

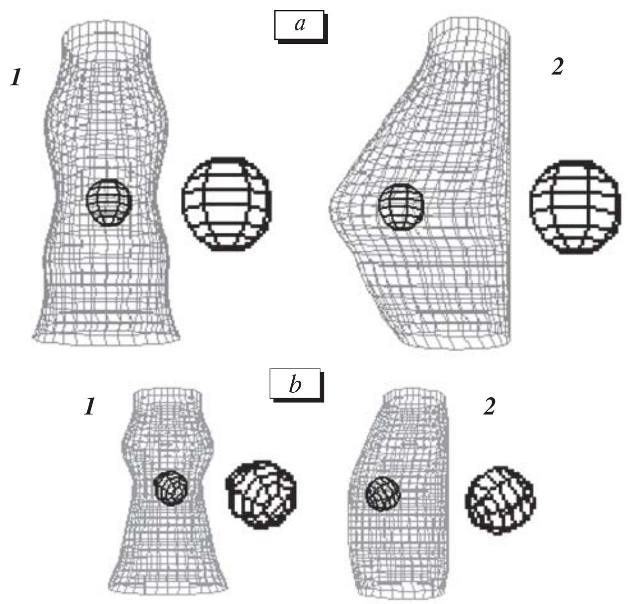

Fig. 1. Models of cardiac and torso surfaces corresponding to the real shapes and mutual position of the heart and the torso during ECG recording. *a*) dog with sharpened shape of the thorax, the apicobasal axis of the heart is parallel to the longitudinal axis of the body; *b*) dog with smoothed shape of the thorax, left posterior deviation of the apicobasal axis of the heart. *1*) front view; *2*) side view.

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coupled the epicardial and surface body potentials by a set of coefficients depending on geometry and mutual spatial position of the heart and body surfaces.

RESULTS

Analysis of changes in CEF on the epicardium and body surface showed that in certain moments of initial ventricular activity, the projection of epicardium potentials onto the torso surface differed in different dogs despite similarity in the epicardial electrical maps (Fig. 2). In individual dogs, the body shape and heart orientation differed significantly: in the frontal plane, the angle of cardiac apicobasal axis varied from -15^o to $+30^o$, while in the sagittal plane, it changed from 0^o to almost $+90^o$. A mathematical model was used to assess the contribution of the body shape and heart orientation into the formation of CEF.

At the first stage, the body surface potentials were modeled according to the individual geometry of dogs. The calculated potentials corresponded the experimental values: the location of positive and negative potentials and their extrema coincided (Fig. 3, *a*), which confirmed adequacy of the applied model.

At the second stage, the body surface potentials were simulated by combining geometrical parameters

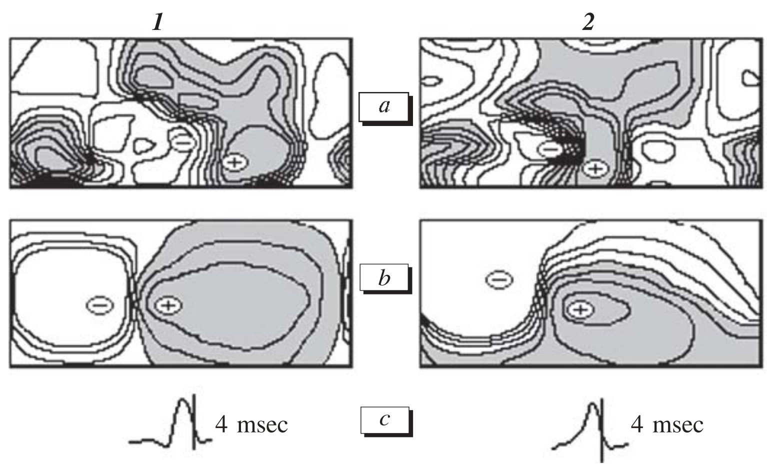

Fig. 2. Instantaneous equipotential distribution of cardiac electric potentials across ventricular epicardium (*a*) and the torso surface (*b*) measured at the same ECG phase in dogs with sharpened (*1*) and smoothed (*2*) shape of the thorax. *c*) QRS-complexes of ECG led from forelimbs with the time marks. Here and in Fig. 3: the left and right panels show potential distribution across ventral and dorsal surfaces of the torso and ventricular epicardium, respectively. Plus and minus mark positions of the extremes. The positive potential areas are hatched. The isolines in epicardium and torso surface are spaced by 5.0 and 0.5 mV, respectively.

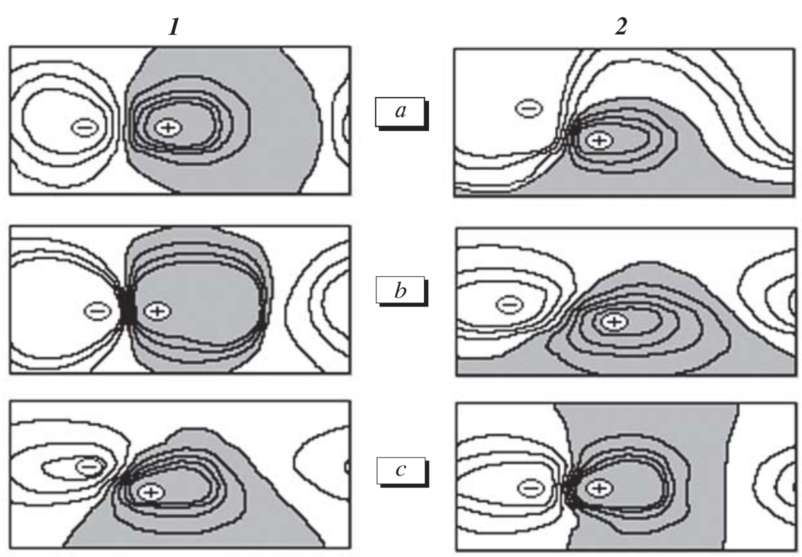

Fig. 3. Calculated instantaneous equipotential distribution of cardiac electric potentials across the torso surface of the dogs with sharpened (*1*) and smoothed (*2*) shape of the thorax. *a*) potentials were calculated with account for individual geometry of the dogs; *b*) potentials were calculated for modified torso shape: the dog 1 was combined with the torso of dog 2 and the dog 2 used the torso of dog 1; *c*) potentials were calculated for modified orientation of the heart: the dog 1 used orientation of the heart in dog 2 and vice versa.

of two dogs in a single model experiments. To this end, dogs with different torso shape were selected: one was a large dog with forwardly protruding and sharp thorax, while the other dog had "smoothened" torso (Fig. 1). In the large dog, the apicobasal axis of the heart was parallel to the longitudinal axis of the body. In the small dog, the apicobasal axis of the heart was inclined about 30° and 45° in the frontal and sagittal planes, respectively (Fig. 1). On the descending phase of ECG led from the forelimbs and measured 4 msec after *R*-wave, both dogs had similar distributions of epicardial potentials, while their distributions of body surface potentials were different at this moment (Fig. 2). This time point was chosen for mathematical simulation.

To assess the effect of body surface geometry on CEF formation, we used the epicardial potentials and heart orientation of one dog, while the torso shape and position of the geometrical center of the heart were taken from the other dog. The change in torso shape had little effect on the results of calculation: the body surface potentials where similar to those obtained for the real torso shape (Fig. 3, *b*).

To evaluate the effect of heart orientation in the thorax on CEF, we used epicardial potentials, torso shape, and position of geometrical center of the heart in one dog, while orientation of the heart was taken from the other dog. The change in heart orientation produced a pronounced effect on calculation: the distribution of body surface potentials became similar to that of the dog whose heart orientation was used in the model (Fig. 3, *c*).

Mathematical simulation of the projections of epicardial potentials onto the body surface was carried out on the basis of the real heart and torso geometry and ECG data of the experimental dogs.

Thus, orientation of the heart in the thorax affects the formation of CEF on the body surface much more than torso geometry.

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