Electrocardiographic Mapping in a Realistic Torso Tank Preparation

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Abstract

This paper contains preliminary findings of mapping transient myocardial ischemia in an isolated heart preparation suspended in an instrumented, human shaped, electrolytic torso tank. The preparation allows us to record both epicardial and tank surface potentials simultaneously and thus capture the dynamic nature of acute ischemia through repeated episodes. Our results demonstrate the utility of the preparation and reveal the need to consider geometrical relationships when using electrocardiographic potentials to estimate cardiac activity.

Introduction

A fundamental research goal in electrocardiography is to characterize the transfer of information from the heart to the body surface. Physical models of a torso containing a real or simulated heart are vehicles uniquely suited to evaluate these relationships. Access to both epicardial and torso surfaces allows a high degree of control over experimental interventions with simultaneous data acquisition from both the source and its reflection on the body surface. By, for example, altering the location or site of pacing in the heart, changing global or local heart temperatures, inducing ischemia, or adding realistically inhomogeneous phantoms, important biophysical and geometrical relationships can be investigated.

In this paper, we offer a sample of preliminary results with a torso tank/isolated heart preparation. We concentrate specifically on the influence of acute myocardial ischemia on epicardial and tank surface potentials. Previously reported studies from this preparation have dealt with inverse modeling [1], interpolation techniques [2], and the effects of local repolarization changes [3] and torso inhomogeneities [4].

Methods

Electrolytic tank, electrodes: The torso tank is a fiberglass shell in the shape of an adolescent thorax containing 374 surface electrodes (5 mm Ag/AgCl pellets). One bank of 192 electrodes corresponds to the standard BSPM configuration of 16 vertical strips of 12 electrodes that is used routinely at the CVRTI.

Isolated heart preparation: The preparation consists of a heart from one animal perfused in a modified Langendorff manner by a second dog providing circulatory support[4]. To induce ischemia in the isolated heart, we applied a snare to a proximal segment of the left anterior descending artery. Voltage signals were acquired simultaneously in 4-second epochs from 64 epicardial and 192 tank surface electrodes. To capture the dynamics of occlusion-induced ischemia, we first recorded with the snare in place but open, then closed the snare and recorded once per minute for three minutes. After releasing the snare we recorded at 1, 3, and 5 minutes.

Results and Discussion

Acute ischemia: We present a particular example from an occlusion experiment that demonstrates the influence of geometrical relationships on information transfer between the heart and body surfaces. Figure 1 contains a sequence of three sets (rows) of maps from tank and epicardial surface recordings. Each row contains two pairs of maps, one pair from the epicardium and the other from the tank surface. Each pair consists of isopotential maps from equivalent instants in two beats, one recorded just before the snare was closed (Pre-occlusion or "PRE"), the other two minutes after occlusion (2 Min. Occlusion or "OCCL"). The timing of the three instants chosen for display is indicated by the vertical lines in the time signals in the figure. Tank surface maps are displayed in a cylindrical projection with the anterior surface in the left half, the posterior surface in the right. The epicardial maps are displayed in apical view with the apex at the center and the left anterior descending artery running from the top towards the center. Spacing between contours is linearly scaled at a fixed interval of 500 μV for the epicardial and 20 μV for the tank surface maps.

Comparing epicardial maps from the first instant of the series, we see elevated potentials (4905 μV) in a small region of the OCCL map, near the 2:00 o'clock position of the apical display; in the PRE map, this feature is not present and a different maximum exists that is much smaller in

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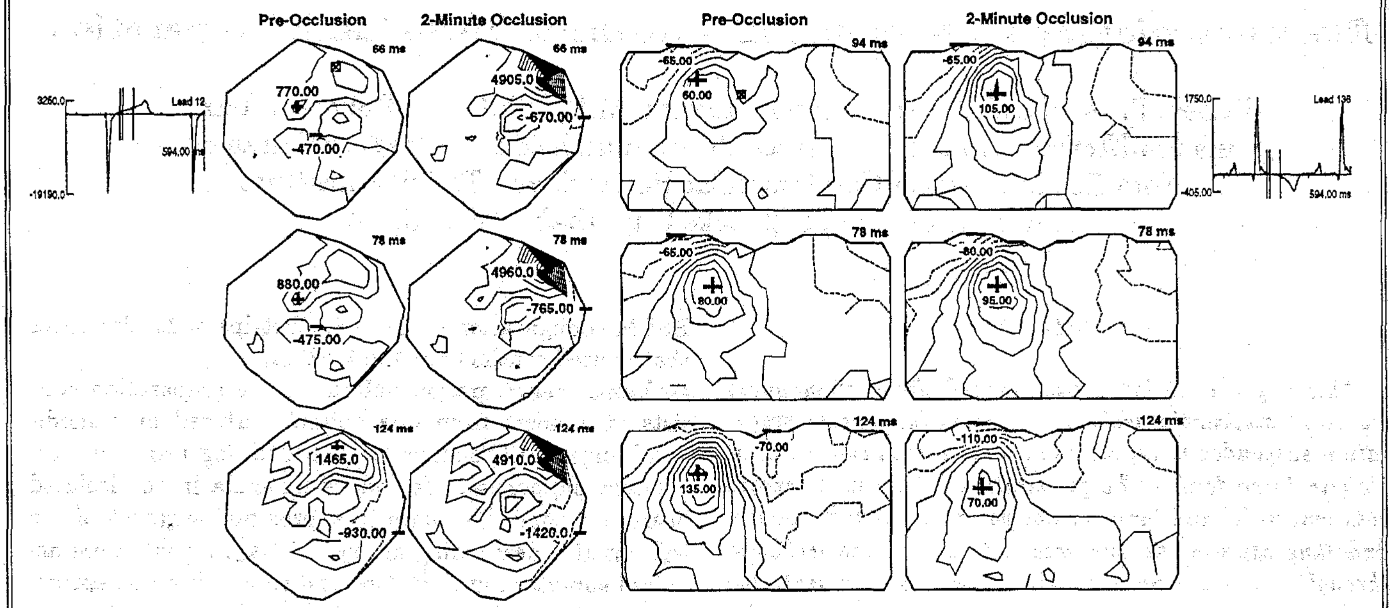

Figure 1: Epicardial and tank surface maps from three equivalent instants during beats recorded before (columns 1 and 3) and 2 minutes after (columns 2 and 4) coronary occlusion.

amplitude (770 μV). On the tank surface, this difference is reflected as a shift and enhancement of the maximum in the OCCL map relative to the PRE map. In the next set of epicardial maps, the topography has not changed, but the amplitudes have shifted slightly; the maximum in the PRE map has increased in amplitude as has the minimum in the OCCL map. Concurrently, the tank surface maps have become more similar in shape and differ only by 15 μV in amplitude.

In the final frame, the epicardial maps have become more similar in shape, but their amplitudes still differ sharply — the OCCL maximum is three times as large (4910 *vs.* 1465 μV). The tank surface maps, however, suggests a contrary interpretation. The PRE map now shows a precordial maximum almost twice as large as that in the OCCL map (135 *vs.* 70 μV). Thus a very focal area of large potential can project more weakly to the body surface than another, larger region of lower strength, a reflection of the sensitivity of the electrocardiographic field to geometrical relationships.

These preliminary results demonstrate the value of the isolated heart/torso tank preparation in both experimental and modeling research. The high level of experimental control, and the ability to record epicardial and tank surface potentials simultaneously will permit us to examine many aspects of electrocardiographic theory and practice.

References

[1] P. Colli Franzone, L. Guerri, B. Taccardi, and C. Viganotti. The direct and inverse problems in electrocardiology. Numerical aspects of some regularization methods and applications to data collected in isolated dog heart experiments. *Lab. Anal. Numerica C.N.R.*, Pub. N:222, 1979.

[2] R.S. MacLeod, R.L. Lux, and B. Taccardi. Translation of body surface maps between different electrode configurations using a three-dimensional interpolation scheme. In P.W. MacFarlane, editor, *Electrocardiology '93: Proceedings of the International Congress on Electrocardiology, XXth Annual Meeting*, pages 179–182. World Scientific, Singapore, 1993.

[3] R.L. Lux, L.S. Green, R.S. Macleod, and B. Taccardi. Assessment of spatial and temporal characteristics of ventricular repolarization from the body surface. *J. Electrocardiol.*, 27 (Supp.):100–104, 1994.

[4] R.S. MacLeod, B. Taccardi, and R.L. Lux. The influence of torso inhomogeneities on epicardial potentials. In *IEEE Computers in Cardiology*, pages 793–796. IEEE Computer Society, 1994.

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