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Imaging 3-dimensional Cardiac Electrical Activity from Intra-Cavity Potentials

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Abstract- **We propose a novel approach to image 3-dimensional (3-D) cardiac electrical activity from intra-cavity electrical potentials. The 3-D cardiac electrical activity is estimated by minimizing the difference between the recorded and model-generated intra-cavity potential distributions. The feasibility of the proposed concept is tested by a computer simulation.**

***Keywords*- cardiac electrical imaging, intra-cavity potentials, catheter, inverse problem, electrocardiographic imaging**

I. INTRODUCTION

It is of importance to localize and image cardiac electrical activity. Inverse problems have been solved image cardiac electrical activity from noninvasive electrocardiograms or magnetocardiograms. Efforts have also been made to measure endocardial activation or reconstruct endocardial electrical activity from intra-cavity potentials.

We propose a new approach to image 3-D cardiac electrical activity from intra-cavity potentials. The concept has been tested in a computer simulation study.

II. IMAGING PRINCIPLES

The concept of the proposed approach is to estimate the 3-D distribution of cardiac electrical activity by minimizing the difference between the recorded and model-generated potential distributions over the surface of a catheter at an instant or during a period. The inverse solution $\hat{J}(t)$ within the 3-D myocardium can be in general expressed as (1)

$$\arg\min_{J(t)}\left(\sum_{t=T_1}^{T_2}\left\|\Phi_{rec}(t)-\Phi_{model}(t)\right\|_{k_1}^{l_1}+\lambda(t)\left\|WJ(t)\right\|_{k_2}^{l_2}\right) \qquad (1)$$

where J(t) is the source distribution, Φ_{rec} and Φ_{model} are the recorded and model-generated electrical potentials over the catheter surface. k_1, k_2, l_1 and l_2 are procedure parameters. (T_1, T_2) refers to the period during which the inverse imaging is performed, where T_1 maybe equal to T_2 for instantaneous imaging. W is a weighting function, and λ *(t)* is regularization parameter. Φ_{model} can be obtained by solving the forward problem from the cardiac electrical sources J(t) to the catheter surface potentials. Thus, the proposed approach consists of two steps: 1) the forward procedure to calculate the catheter surface potential maps (CSPMs) from cardiac sources; and 2) the inverse procedure to estimate 3-D cardiac electrical activity from the CSPMs.

III. COMPUTER SIMULATION

A computer simulation was conducted to test the proposed concept of 3-D electrical imaging from CSPM. A realistic geometry finite element heart-torso model was constructed which includes a recording catheter located in the left ventricle (LV). Cardiac electrical activity was simulated with the aid of a cellular-automaton heart-excitation model [1] under single pacing condition. Gaussian white noise of 25 μV was added to the computed CSPMs to simulated noise-contaminated measurements. A nonlinear optimization procedure [1-2] was used in this computer simulation to minimize the difference between simulated CSPMs and the model-generated CSPMs, and to estimate the activation sequence. Fig. 1 shows an example of the 3-D activation imaging results estimated from intra-cavity potentials at 64 sites. The top and bottom rows refer to the target "true" and inversely estimated 3-D activation sequences, respectively. The pacing location is shown by a yellow dot located at posterior left ventricle.

V. DISCUSSION

We have proposed a novel approach for 3-D cardiac electrical imaging from intra-cavity potential recordings. With the aid of catheter mapping of intra-cavity potentials at multiple sites simultaneously, the present approach represents an important advancement over conventional approaches by offering the 3-D ability for localizing and imaging of cardiac electrical activity. The intra-cavity potentials can be measured by a catheter within the blood cavity or over the endocardial surface. The promising pilot computer simulation study suggests the feasibility of the proposed approach in imaging 3-D cardiac activation. Other electrophysiological properties can also be estimated based on the proposed approach using various imaging algorithms such as (1). The proposed approach may be useful in aiding catheter ablation of cardiac arrhythmias, and diagnosis and management of a variety of cardiovascular diseases.

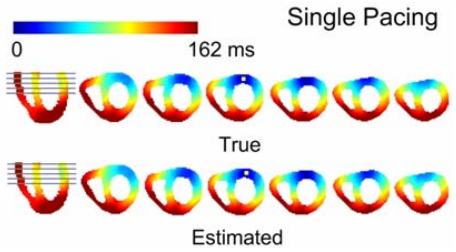

Fig.1 Computer simulation of 3-D cardiac activation imaging from intra-cavity potentials.

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REFERENCES

[1] G. Li, B. He, "Localization of the site of origin of cardiac activation by means of a heart-model-based electrocardiographic imaging approach," *IEEE Trans. Biomed. Eng.*, Vol. 48, pp. 660-669, 2001.

[2] B. He, G. Li, X. Zhang, "Noninvasive three-dimensional activation time imaging of ventricular excitation by means of a heart-excitation model," *Phys. Med. Biol.*, Vol. 47, pp. 4063-4078, 2002.

[3] B. He, G. Li, X. Zhang, "Noninvasive imaging of cardiac transmem-brane potentials within three-dimensional myocardium by means of a realistic geometry anisotropic heart model," *IEEE Trans. Biomed. Eng.*, Vol. 50, pp. 1190-1202, 2003.