

An Experimental Study of 3-dimensional Cardiac Electrical Imaging in a Swine Model

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Abstract

We have conducted an experimental study to validate a previously developed 3-dimensional cardiac electrical imaging (3DCEI) method in a control large animal (swine) during intramural and endocardial pacing. Single-site pacing was conducted from both intramural and endocardial locations. During pacing, body surface potential mapping and intracavitary mapping (by Ensite 3000 endocardial mapping system) were performed simultaneously. The 3DCEI analysis was performed on the measured BSPMs. The averaged localization error of IS was 7.4 mm. The extracted endocardial ASs from the estimated 3D ASs by 3DCEI were consistent with the endocardial ASs reconstructed from the intracavitary mapping by the Ensite system. The present experimental results demonstrate that the noninvasive 3DCEI approach can localize the IS with good accuracy and estimate AS under an in vivo setting.

1. Introduction

Noninvasive mapping of the arrhythmic activities by analyzing the thoracic ECG recordings is of enormous value, because it allows cardiologists to localize the arrhythmic substrate before the intervention and to focus the intervention at the source of the arrhythmia without the need for lengthy intra-cardiac mapping. Recently, He and co-workers proposed and developed the 3-dimensional cardiac electrical imaging (3DCEI) approach for noninvasively imaging 3-dimensional cardiac electrical activity from BSPMs [1-8]. Promising results have been obtained by a series of computer simulations, and in a rabbit model in comparison with 3D intracardiac mapping [8].

The aim of the present study was to validate the 3DCEI method in a swine model whose size, heart-torso geometry and electrophysiological characteristics are closer to the human's. The results are compared with the endocardial mapping results obtained using a clinically practiced endocardial mapping system.

2. Methods

The detailed 3DCEI algorithms were described previously [2,3,8]. In the present study, the pre-operative magnetic resonance imaging (MRI) was performed on the animal before the *in vivo* mapping study to obtain the anatomical geometry information. During the study, ventricular pacing was performed by an intramural pacing lead in the right ventricle (RV) and by an electrophysiology (EP) catheter in the left ventricle (LV). The surgery protocol has been previously developed [9]. The Ensite 3000 system (St. Jude Medical Inc.) was configured for the intracavitary mapping and a multi-electrode catheter was put into the left ventricle. For the body surface potential mapping, 81 disposable electrodes were placed on the anterolateral chest and connected to the SynAmps² amplifier system (Neuroscan Labs, TX). The intracavitary potential mapping and the body surface potential mapping were performed simultaneously during ventricular pacing. The location of the pacing site in RV was obtained by scanning the isolated heart with the intramural pacing lead remaining in place using MRI; the location of the pacing site in LV was recorded by the Ensite system. Then the 3DCEI approach was applied on the measured BSPMs. The noninvasively estimated locations of the initiation sites were compared with the pacing locations. The 3D activation sequence throughout the myocardium was also noninvasively estimated by 3DCEI. The endocardial activation sequence was extracted from the 3D activation sequence and compared with the endocardial activation sequence reconstructed by the Ensite system.

3. Results

In RV area, the pig's heart was intramurally paced from RV apex (RVA). In LV area, the heart was endocardially paced from LV anterior (LVAn). In

total, pacing was performed at 2 different sites and 20 paced beats were analyzed (10 for each site). The averaged localization error of the initiation site at RVA was 7.9 ± 0.7 mm, and 6.9 ± 1.9 mm at LVAn. Figure 1 shows an example of the imaging results when the pig was paced from the LV anterior. The activation sequence (AS) on the endocardium of LV is shown in panel (a) from three viewing angles: RAO, AP and LAO. The AS estimated by 3DCEI (lower row) was compared with the AS reconstructed by the Ensite system (upper row). The earliest activated site is shown in deep red, which is indicated by number "1" on the figure. The latest activated site is shown in blue, indicated by number "2". It is observed in panel (a) that the AS estimated by 3DCEI is consistent in general pattern with that reconstructed by the Ensite system. In panel (b), the precise and the estimated location of the initiation site of activation are shown and compared. In this typical example, the localization error (LE) was as small as 5 mm. The estimated 3D activation sequence throughout the ventricles is also shown, from which the estimated endocardial activation sequence shown in panel (a) is extracted.

4. Discussion

In the present study, we have conducted an experimental study to assess the 3D cardiac electrical imaging approach in a large animal model under well controlled protocol. We used the pacing protocol to generate physiologically realistic but well controlled ventricular activation and evaluated our imaging algorithm by comparing with the pacing sites as determined by other means, as well as with the endocardial mapping results. The experiment was conducted under a completely in vivo setting, and revealed promising results of localizing ventricular electrical activity in the 3D space. The comparison with the endocardial mapping results provides a reasonable means of assessing noninvasive imaging methods by using the minimally invasive procedure. The present promising results indicate that the 3DCEI merits further investigation and may provide a useful

tool for assessing cardiac electrical activity in the 3D myocardial volume.

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5. References

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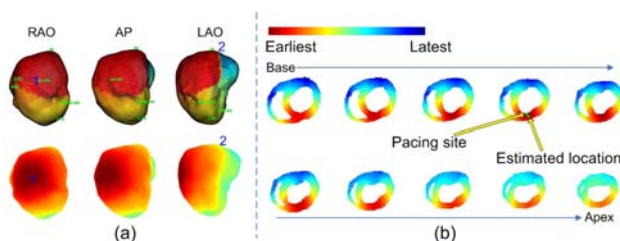


Figure 1. An example of inverse results when the heart is paced from left ventricular anterior.