Comparison of Left Ventricular Late Activation Zones Determined Using Noninvasive Electrocardiographic Imaging With Sequential Computed and Magnetic Resonance Tomography

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Abstract

Recently, noninvasive electrocardiographic imaging (ECGI) has been introduced into the clinical practice. Although the ECGI diagnostic accuracy in combination with computed tomography (CT) was previously reported, the question of validating this technique with use of magnetic resonance imaging (MRI) was not solved. In this article, the method of comparison between left ventricular late activation zones determined by ECGI and sequential CT and MRI is presented. To demonstrate performance of the proposed methodology, we studied eleven patients before implantation devices for cardiac resynchronization therapy. The reconstructed three-dimensional CT and MRI models of the ventricles were merged using custom software written in Python. The median (LQ; UQ) mismatch in the obtained late activation zones was 12 (7; 13) mm. Minimal distance was 1 mm, while the maximum error was 20 mm. To conclude, this study is the first attempt to validate the accuracy of ECGI in combination with MRI against the CT-based gold standard in determining the late activation zones.

1. Introduction

Noninvasive electrocardiographic imaging (ECGI) is a modern diagnostic direction in arrhythmology, based on solving the inverse problem of electrocardiography. A number of methods for solving this problem has been previously published (see e.g. [1-4]). The technique, we use in the present work, is known as ECGI.
It implies a combined application of multichannel electrocardiography and computer (CT) or magnetic resonance imaging (MRI) data. The diagnostic accuracy of the ECGI application in combination with the CT scans was previously reported [5]. Isopotential maps, constructed from non-invasively reconstructed unipolar electrograms, demonstrated quite accurately the early activation zone on a 3-D CT model of the heart. The concept of assessing the late activation zone based on isopotential maps is very similar: We consider the same map on a CT model for further visual analysis of the late activation zone. In clinical practice, though, preference is given to MRI, as it is not associated with radiation exposure. In the present work, we describe a working pipeline for combining ECGI with sequential CT and MRI for noninvasive detection of the left ventricular late activation zones. To provide a proof-of-concept for the developed workflow, we studied eleven candidates for cardiac resynchronization therapy (CRT), merged their CT and MRI cardiac anatomical data, and, finally, assessed the mismatch in resulting isopotential maps.

2. Materials

In Figure 1, we show the workflow of the study, described in this section.

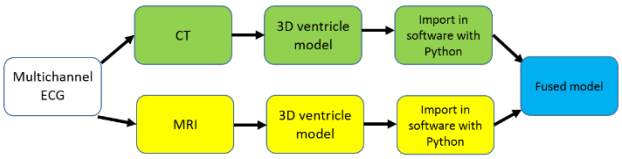

Figure. 1. Workflow of the study for noninvasive detection of late activation zone in patients before CRT.

2.1. Patient data

The study population consisted of 11 consecutive patients scheduled for CRT device implantation. The median (min; max) age was 67 (55; 78) years. Ten examined subjects had sinus rhythm with complete left bundle branch block activation pattern, whereas one patient showed a left anterior bundle branch block

 ISSN: 2325-887X DOI: 10.22489/CinC.2018.347

activation. All participants signed informed written consent before the procedure, describing the scope and goals of the investigation. The study was approved by the local Ethics Committee of the Almazov National Medical Research Centre.

2.2. ECG recording

A maximum of 240 unipolar body surface mapping electrodes compatible with CT and MRI were placed onto the patients' torsos. Body surface ECG were recorded during sinus rhythm on Amycard 01C EP LAB system (EP Solutions SA, Switzerland).

2.3 Tomography imaging

Firstly, torso and cardiac CT scan were performed. We used Somatom Definition 64, Siemens AG. Low dose scan revealed positions of body surface electrodes and individual torso anatomy. ECG gated scan of the heart was done using automated intravenous injection of a non-ionic contrast (Ultravist 100 ml) during breath hold. In addition to scientific clinical data, all patients received a CT conclusion about their coronary sinus anatomy.

Torso and cardiac MRI scans (MAGNETOM Trio A Tim 3 T, Siemens AG, Germany) were implemented on breath hold and without ECG synchronization in 2 hours after the CT. Torso MRI scans resulted in the same anatomical contours as the CT-based body models. MRI scan of the heart was done using intravenous injection of a contrast (Gadovist 15 ml). In addition to scientific clinical data, the participants obtained a MRI conclusion about structural changes (scar, post inflammatory fibrosis) of their left ventricles.

2.4 Data analysis

Individual epicardial models of the heart ventricles were reconstructed, using MRI and CT data separately. The activation of the LV epicardium was evaluated using software of Amycard 01C EP LAB system. Late activation zone was determined based on isopotential maps. This area was estimated manually as a latest depolarization of the LV. We marked the center of the late zone using the black dot (fig. 2, 3).

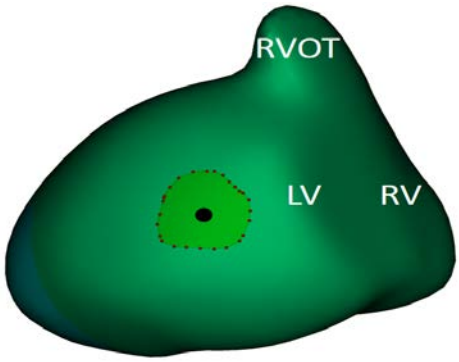

Figure. 2. Example of a reconstructed epicardial polygonal model using computed tomography. Isopotential map. Black dot – central marker of late activation zone. LV and RV – left and right ventricles. RVOT – right ventricular outflow track. Posterior-anterior projection.

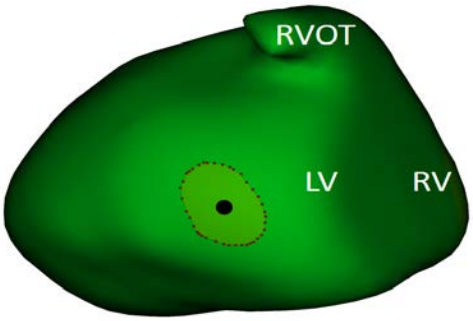

Figure. 3. Example of a reconstructed epicardial polygonal model using magnetic resonance tomography. Isopotential map. Black dot – central marker of late activation zone. LV and RV – left and right ventricles. RVOT – right ventricular outflow track. Posterior-anterior projection.

Reconstructed polygonal epicardial models based on CT and MRI were imported in text format into a custom written software in Python (Python Software Foundation).

Finally, CT and MRI models were fused using the iterative closest point algorithm. Quantitative mismatch of late activation zones on the fused models was assessed by measuring the distance between the black dots (fig. 4).

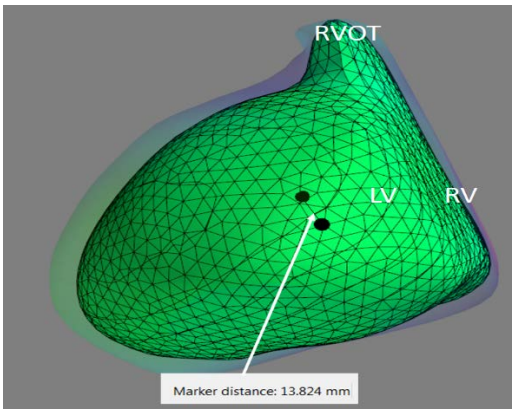

Figure. 4. Epicardial merged model with Python. Black dot – center marker of late activation zone on CT and MRI model. Marker distance = 13.8 mm.

2.5 Statistics

The statistical analysis was performed using the statistical software package STATISTICA v.12 (StatSoft Inc., USA). The median, quartiles (LQ; UQ), min and max values were calculated for continuous variables.

3. Results

Clinical and instrumental data of the examined patients (table 1).

Table 1. Participants' data

Parameters	Value
IHD/DCM, n	8/3
QRS, ms	195(165;215)*
LV EF, %	25(20;29)
LVEDD, mm	72(67;83)
LVESD, mm	66(60;75)
LVEDV, ml	262(200;395)
LVESV, ml	202(160;281)

IHD – ischemic heart disease; DCM – dilated cardiomyopathy, LV EF – ejection of fraction left ventricle; EDD and EDV – end diastolic diameter and volume; ESD and ESV – end systolic diameter and volume, * – median (LQ; UQ)

On the fused models median (LQ; UQ) distance between black dots was calculated automatically and equaled 12 (7; 13) mm. Minimal distance was 1 mm. Maximum distance was 20 mm.

4. Conclusion

Implementation of merging CT and MRI models revealed absence of significant difference between marked centers of the late activation zones. The highest mismatch did not exceed 20 mm, indicating applicability of the logistically and ethically favourable MRI scanning for ECGI. This study was, to our knowledge, the first to validate the accuracy of determining the late activation zone with a combination of ECGI and MRI against the commonly used CT-based anatomical reference.

Acknowledgements

This work was supported by the Russian Foundation for Basic Research (grant № 18-315-00261\18).

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