Noninvasive Electrocardiographic Imaging with Magnetic Resonance Tomography in Candidates for Cardiac Resynchronization Therapy

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Abstract

Noninvasive electrocardiographic imaging (ECGI) with magnetic resonance tomography (MRI) is a promising technology raising clinical interest. In this manuscript, the method of qualitative comparison of late electrical activation zone's position and area of fibrosis based on 17-segment approach is presented. To demonstrate performance of the proposed method, we studied sixty one patients scheduled as a potential candidates for cardiac resynchronization therapy. ECGI was performed using Amycard 01C EP LAB (EP Solutions SA, Switzerland). The late activation zone (LAZ) on a wide QRS complex with different morphology pattern was variable from anterior till inferior left ventricle (LV) wall. According to the MRI data, 41(67%) patients had fibrosis areas which did not coincide with the LAZ. 9(15%) participants had transmural scar involving epicardium of LV which localization coincided with the LAZ. In the remaining 11(18%) cases non-transmural scar excluding epicardial layer coincided with the LAZ. Taking these results into account, it is reasonable to assume that comparative qualitative analysis of ECGI and MRI data demonstrates coincidence of LAZ with fibrosis areas only in 33% of cases.

1. Introduction

Due to the widening of the QRS complex, myocardial dyssynchrony is formed. It causes a disturbance of systolic and diastolic functions, mitral and tricuspid insufficiency, underlying the pathogenesis of chronic heart failure [1]. One of the outstanding approaches for the correction of ventricle abnormal contraction is the method of cardiac resynchronization therapy (CRT) [2].

In many cases the dyssynchrony is associated with presence of fibrotic tissue in the left ventricle (LV), slowing down the normal excitation spread. Therefore, it is advisable to position the LV electrode in the late activation zone (LAZ) without fibrotic tissue [3]. A crucial condition in such case is the absence of an epicardial scar in the LV area of interest. This requirement is dictated by the practical reason, since the LV electrode is mainly implanted by transvenous access from the side of the epicardium.

TARGET and STARTER studies have demonstrated feasibility of this lead positioning strategy using echocardiography [4, 5]. Nevertheless, there are some significant limitations to this approach to be taken into account: not always satisfactory quality of images, interobserver discrepancy of results during assessment of fibrotic area.

With this respect, magnetic resonance imaging (MRI) represents an optimal tool for visualizing structural changes in the myocardium [6]. However, electrical information, including LAZ, remains invisible for MRI.

To address this drawback, another method – noninvasive electrocardiographic imaging (ECGI) – is currently being developed, whereby its combination with MRI is considered to have a promising potential as a diagnostic tool in a clinical practice [7].

In the present work, we analyze both approaches and compare electrical LAZ provided by ECGI and the structural changes in the LV myocardium in candidates for CRT.

2. Materials

In Fig. 1, we show the workflow of the study, including data acquisition and processing.

2.1. Patient data

To provide a proof-of-concept for the developed workflow, we studied sixty one consecutive patients scheduled before CRT device implantation. The age at enrolment was 65 (47; 83) – median (min; max) years. Sixty examined subjects had sinus rhythm and the last one- atrial fibrillation without high frequency during

 ISSN: 2325-887X DOI: 10.22489/CinC.2019.397

examination. The written informed consent was obtained from each patient before the procedure. The study was approved by the local Ethics Committee of the Almazov National Medical Research Centre.

2.2. ECG recording

Up to 240 unipolar body surface mapping MRI compatible electrodes were applied on the patient's torso. Multichannel electrocardiography as a first step of ECGI was done on Amycard 01C EP LAB (EP Solutions SA, Switzerland).

2.3 Tomography imaging

Thoracic and cardiac MRI scans (MAGNETOM Trio A Tim 3 T, Siemens AG and INGENIA 1.5 T, Philips) were implemented on breath hold and without ECG synchronization. Torso MRI scan captured all applied ECG stripes. Scanning of the heart was done twice after intravenous injection of a contrast (Gadovist 15 ml). First block of slices was collected in 5-7 minutes after drug administration. This series were later used for heart model reconstruction. Late gadolinium enhancement was estimated in 15 minutes, in order to identify fibrosis areas.

2.4 Data analysis

The obtained ECG and MRI data were imported into Amycard 01C EP LAB software. Individual epicardial models of the heart ventricles were reconstructed based on semi-automatic segmentation. On the one hand, late activation zone during ventricles depolarization was determined using isopotential maps (Fig. 2). This area was estimated manually as a latest depolarization of the LV. On the other hand, two independent radiologists evaluated localization and myocardial layers involved in fibrosis using standard 17-segmented scheme [8] of the LV (Fig. 3). Finally, we performed qualitative comparison of the LAZ and fibrosis areas based on 17-segment approach.

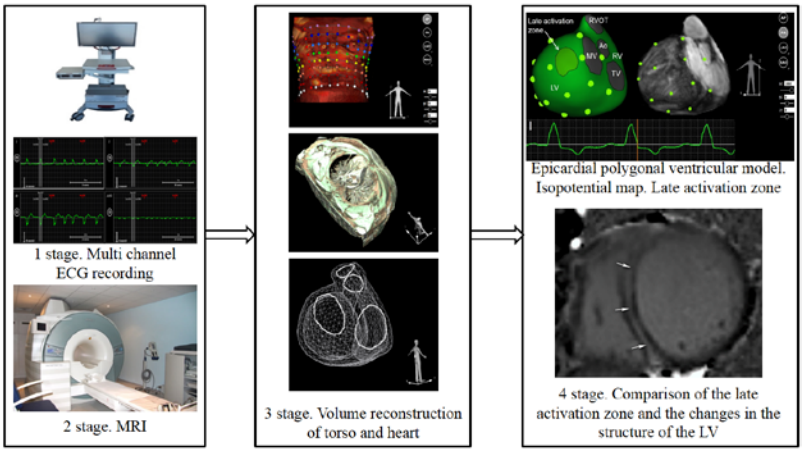

Figure. 1. Workflow of the study for noninvasive detection of late activation zone and fibrosis in patients before CRT.

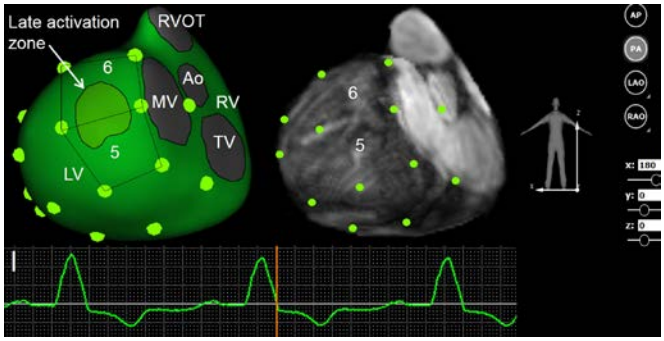

Figure. 2. Example of a reconstructed epicardial polygonal model. Isopotential map. Late activation zone is between 5th and 6th standard segments of left ventricle. RVOT – right ventricle outflow track. Ao – aorta. MV, TV – mitral and tricuspid valve.

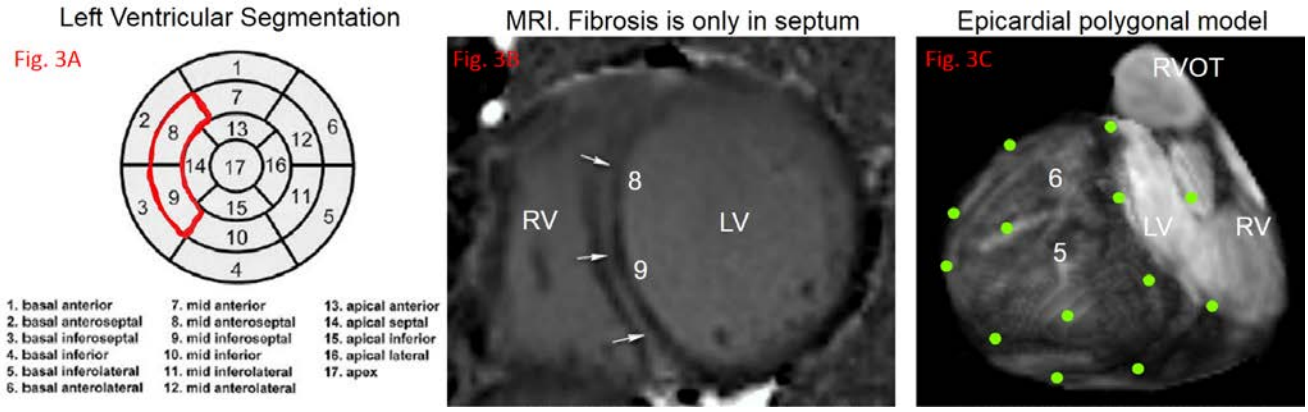

Figure. 3. A) Standard 17-segmented scheme. In this example 8th and 9th segments include fibrosis. Therefore they are marked with a read outline. B) Example of revealing fibrosis only in 8th and 9th segments using MRI data.
C) The same example of a reconstructed epicardial polygonal model. 5th and 6th segments do not include fibrosis.

2.5 Statistics

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

3. Results

Clinical data of the examined patients (Table 1).

Table 1. Patient data

Parameters	Value
IHD/DCM, n	36/25
MI in the past	33
QRS, ms	200(141;240)*
LV EF, %	24(14;35)
LVEDD, mm	71(57;95)
LVESD, mm	61(43;84)
LVEDV, ml	279(154;594)
LVESV, ml	211(111;458)

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

Morphology of QRS pattern was diverse. 31 participants had complete left bundle branch block (LBBB) without significant deviation of QRS axis, in 22 cases – LBBB with significant deviation of QRS axis, in 3 cases – left anterior fascicular block, in 5 cases – nonspecific wide QRS complex.

The study revealed different positions of LAZ in cases with similar QRS morphology. In Fig.4 we show an example of two patients with complete LBBB without significant deviation of QRS axis in both cases. Patient 'A' (upper row) had this zone between inferolateral and anterolateral basal segments. Patient 'B' had the LAZ in the inferolateral middle segment (Fig. 4).

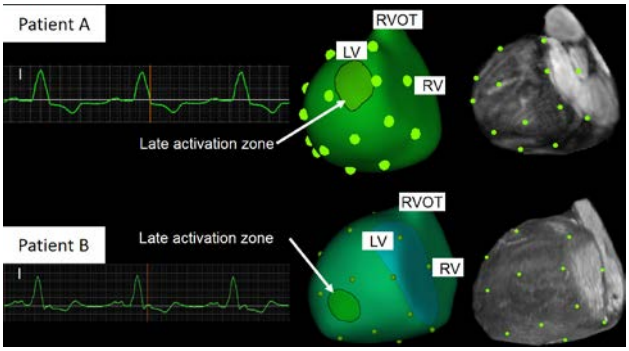

Figure. 4. Isopotential map for the epicardial ventricle model. Positions of the late activation zone are not the same.

Fig. 5 shows distribution of LAZ as found by ECGI across different segments. More frequently it was revealed between inferolateral and anterolateral basal segments of LV – 25 cases (40%). Isolated anterolateral basal segment was involved in 14 subjects (23%). Isolated inferolateral basal segment was involved in 8 cases (13%). Another locations were found in 24% of the cases.

According to the MRI data, 41(67%) patients had fibrosis areas which did not coincide with the electrical LAZ. 9(15%) participants had transmural scar including epicardium of LV, whose locations coincided with the respective LAZ. In the remaining 11(18%) cases non-transmural scar excluding epicardial layer showed a good agreement with LAZ (Fig. 6).

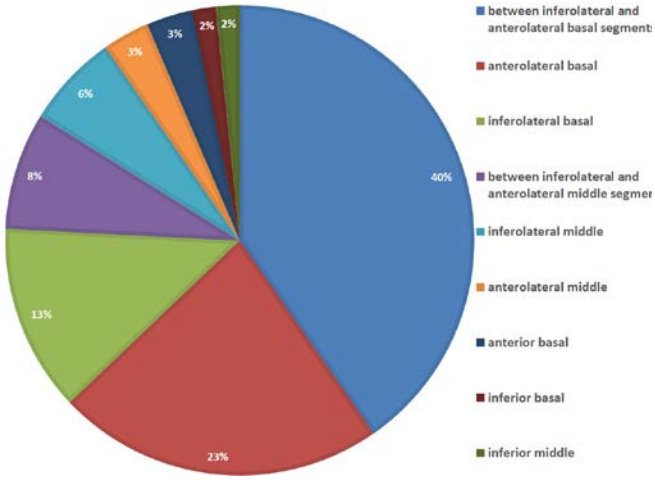

Figure. 5. Location of late activation zone on epicardial surface of left ventricle.

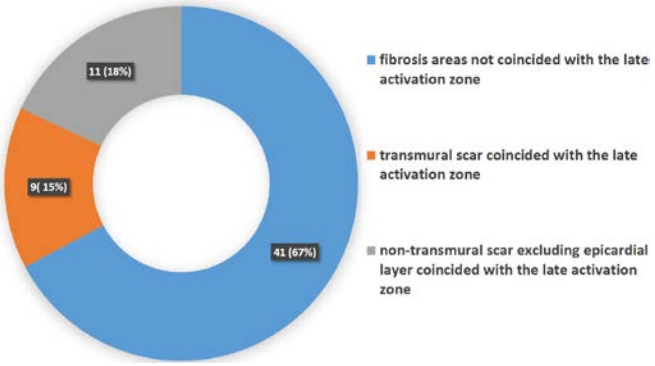

Figure. 6. Comparison of late activation zone and fibrosis areas.

4. Discussion and conclusions

Comparative qualitative analysis of ECGI and MRI data demonstrates overlap of LAZ with fibrosis areas in 33% of cases. This fact indicates that some LAZ' due to the scar tissue are missing by ECGI.

The most challenging cases are those having a transmural scar coinciding with the ECGI-based LAZ. In such situation we have to recommend implantation of the LV electrode not in the LAZ directly. These patients are more probable to be non-responders to CRT.

Interestingly, some of the patients with similar QRS morphology had different LAZ as a target. This can be explained by various locations of fibrotic tissue, which slows down the excitation spread unequally.

In general, ECGI with MRI has an advantage over MRI by itself, since visualizing simultaneously both the electrical LAZ and fibrosis areas can reveal a still viable tissue with late activation as an optimal target for LV lead placement.

Acknowledgements

This work was supported by the Russian Foundation for Basic Research (grant № 18-315-00261\19).

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