High-resolution CSPAMM rat heart tagging on a 1.5T clinical MR system

M. K. Ivancevic[1], J-L. Daire[1], J-N. Hyacinthe[1], G. Crelier[2], S. Kozerke[2], K. Montet-Abou[1], I. Tatar[1], D. R. Morel[3], J-P. Vallee[1]

[1]Radiology, Geneva University Hospital, Geneva, Switzerland, [2]Institute for Biomedical Engineering, University and ETH, Zurich, Switzerland, [3]Anesthesiology, Geneva University Hospital, Geneva, Switzerland

Introducion

MRI has been largely used to measure myocardial mass, end-systolic and end-diastolic volumes, ejection fraction (EF) and aortic bloodflow. However, in coronary artery disease (CAD) evaluation, it is important to complete the global function measurement by regional function evaluation. Myocardial contraction defect is an early indicator of ischemic disease and treatment response. MRI cardiac tagging allows regional myocardial strain quantification with the possibility of transmural resolution. There is an increasing need to quantify myocardial contraction at a subendocardial scale in small rodents, which have acquired a central role in studying mechanisms of cardiovascular disease in recent years. However, tag imaging of small animals has significant challenges due to the high cardiac frequency and the small FOV required. It has only been performed on high field (>4T) research-dedicated MR systems. The aim of this work is to perform a feasibility study of MR-tagging at 1.5T on an occlusion-reperfusion model in rat heart.

Methods

Ten Sprague-Dawley rats (407 ± 49 g) were included in the study, seven infarcted and three normal. Infarction was induced by 30 minutes of occlusion of the main coronary artery followed by reperfusion. Imaging was carried out 6 to 8 hours after the occlusion-reperfusion. Physiology monitoring and ECG gating was performed using an MR-compatible monitoring and gating system (SA Instrument, Inc, Stony Brook, NY). MR images were acquired on an Intera 1.5T system (R9, Philips Medical Systems, Best, NL) with C-SPAMM [1] tag preparation, 1 mm tag distance, segmented cine FFE sequence, 47 mm surface micro-coil, ECG trigger, free breathing, TR/TE 12/6 ms, FA 10°, 128x256 matrix, Cartesian sampling, 80 mm FOV, 2 mm slice thickness, and 11 to 14 cardiac phases, depending on heart rate. Total scan duration per slice was around 1:50 minutes. Images were analyzed using peak-combination HARP method [2,3]. Myocardial strain was calculated from the tracked contours in four cardiac sectors (septal, anterior, lateral and inferior) and classified as normal or infarct based on delayed enhancement after contrast media (0.6 ml Dotarem, Guerbet, France).

Results

Good image quality (fig. 1) for analysis was obtained in 5 of the 7 infarcted rats and in all normal rats. Two of the infarcted cases were excluded from the study due to significant flow and motion artifacts and ECG irregularities. Out of 60 sectors analyzed in infarcted rats, 38 were normal and 22 were infarcted (9 anterior, 9 lateral, 2 septal and 2 inferior). Average myocardial strain in normal rats was 0.23 (±0.1), or by regions: 0.33 (±0.08) in endocardium, 0.22 (±0.05) in midwall and 0.14 (±0.05) in epicardium ($p<0.001$). In rats with myocardial infarction myocardial strain measured in remote and infarcted sectors were: 0.33 (±0.1) and 0.18 (±0.08) in endocardial, 0.19 (±0.12) and 0.072 (±0.038) in midwall, and 0.183 (±0.055) and 0.072 (±0.042) in epicardial regions ($p<0.0001$) on average (fig. 2). Residual but decreased contraction remains in the antero-lateral region attributed to preserved but stunned subepicardial myocardium (fig. 1).

Discussion

Despite difficulties associated with small animal heart imaging, tag images of good quality were acquired and successfully evaluated with the HARP method. Sufficient spatial resolution was obtained to measure transmural differences in myocardial strains. A strain gradient from epicardium to endocardium was consistently observed in the rat myocardium. Decreased myocardial strain was observed in infarcted regions with a preservation of the transmural gradient. In conclusion, the feasibility of cardiac tagging in rats has successfully been demonstrated at a clinical 1.5T system. This study demonstrates the potential of MR tagging for cardiac function assessment in small animal models.

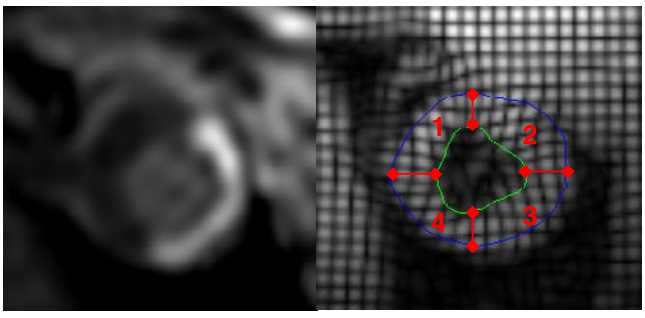

Figure 1. Late-enhancement image of the infarct in the lateral and anterior sector of the heart corresponding to the tag images from figure 2 (left), and (right) sector localization on the corresponding tag image (1: septal, 2: anterior, 3: lateral, 4: inferior).

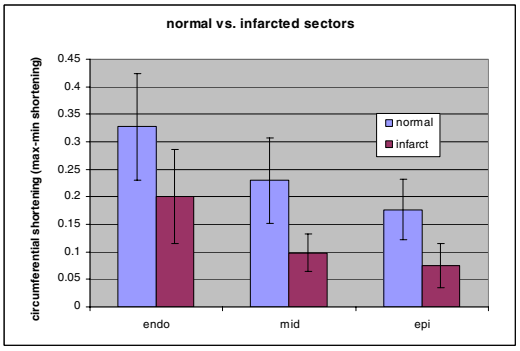

Figure 2. Myocardial strain difference in infarcted and normal sectors in endocardial, midwall and epicardial regions (average over all infarcted rats).

References:

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