Rodent Cardiac MRI on 3T clinical scanner: comparison with 4.7T

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Introduction

Magnetic resonance imaging (MRI) is considered to be a gold standard for non-invasive assessment of cardiac structure and function and it's widely used in clinics and for research. To utilize advanced features of human scanners and minimize the technological gap confounding animal-to-human translational research, it is beneficial to perform small animal imaging on a human scanner. Experience in small animal cardiac MRI on clinical scanners is very limited [1, 2]. Cardiac MRI of small animals using a clinical whole body scanner is a technically challenging procedure due to low gradient strength, heart rate limitation and other human-adapted scanner settings. The purpose of this study was to develop a cardiac MRI protocol to image rodents non-invasively on 3T whole body scanner and to compare measurements of rat cardiac function using 4.7T animal scanner and that from 3T scanner.

Methods

Eight infarcted Sprague Dawley rats (4 weeks after ligation of the main coronary artery) were studied by ^{1}H MRI using a 4.7T Varian (Varian, Inc., Palo Alto, CA, USA) scanner and Philips 3T Achieva whole body scanner (Philips Medical Systems, Netherlands). The animal population used in this work was shared with another study focused on the heart function evaluation after experimental myocardial infarction. All animals were anesthetized for imaging with 1.5% isoflurane in oxygen (inhalation anesthesia). Image parameters for 4.7T Varian scanner: spin-echo multi-slice pulse sequence (SEMS), FOV of 50x50 mm^2; 2D matrix of 256x128; slice thickness 1.5 mm without gap between slices, TR 500ms; TE 15ms; flip angle 90°; NSA 2; spatial resolution 195x390μm. Custom-constructed ^{1}H volume transmit-receive coil has been used at 4.7T scanner. A 4 channel human wrist coil has been used at 3T Philips scanner to image rats. Image parameters for 3T Philips Achieva scanner: proton-density turbo spin echo pulse sequence with black blood pre-pulse (PD_TSE_BB); slice thickness 1.5 mm; FOV 60x45 mm; TR 632 ms; TE 10 ms; ETL 4; NSA 2; acquisition matrix 256x192, spatial resolution 234x234μm. Needle subcutaneous electrodes and commercially available software (SA Instrument, Inc., Stony Brook, NY) were used to trigger MR acquisitions on both scanners. Due to the heart rate limitations at 3T human scanner at 250 bpm (actual rat heart rate is about 400 bpm) we were triggering MR acquisitions on every other heart beat using SA Instrument software. Prospectively triggered, Cartesian turbo-gradient echo cine (TFE_CINE) of a single short-axis slice has been used on 3T scanner to determine delay time for end systole and end diastole. Image parameters for TFE_CINE: slice thickness 2.0 mm, TR 7.7 ms, TE 4.4 ms; FOV 70x49 mm, NSA 4, flip angle 30°, acquisition matrix 128x128, 39 phases per 2 cardiac cycles, phase interval 8.7 ms. Exact delay time for MR acquisitions on 4.7T Varian scanner was determined directly using SA Instrument software. All MR images were obtained at the short-axis of the heart for end systole and another for end diastole to quantify left ventricular function. Epicardial and endocardial borders were manually traced for determination of left ventricular volumes at the end systole and end diastole (ESV, EDV), stroke volume (SV), left ventricular mass (LV mass), and ejection fraction (EF) using software ImageJ 1.34s (NIH, USA). Statistical analysis has been done using paired t-test (Microsoft Excel, Redmond, WA, USA).

Results

The single-slice TFE_CINE sequence on the whole body scanner provided sufficient image quality for determination of systolic and diastolic timing. However, a multi-slice version of the same cine sequence (1.5 mm thickness, no gap), thus far, has not provided adequate information for determination of rat myocardial function, due to an increase in the minimum phase interval. For assessment of myocardial function on the human scanner, several sequential slices covering the entire rat heart were acquired using the PD_TSE_BB pulse sequence at the single phase (end systole or end diastole). The results of this study did not show significant difference in the evaluation of rat cardiac function *in vivo* using 4.7T Varian dedicated animal scanner vs. Philips 3T Achieva human whole body scanner (Table 1). Larger dispersion in measurements on 3T scanner is caused by slightly lower signal-to-noise ratio on clinical scale MR scanner compare to 4.7T Varian scanner. Representative MR images of the rat heart acquired on Philips 3T Achieva scanner and 4.7T Varian MR scanner are shown on Figure 1.

Table 1. Assessment of rat cardiac function on 4.7T Varian scanner and on Philips 3T Achieva scanner. All numbers are shown as mean ± standard error of mean. P values > 0.05 show no statistically significant differences in measurements taken on 4.7T vs. 3T scanners

	4.7T Varian	3T Philips	P value
HR, bpm	391.38±9.37	405±7.25	0.1739
ESV, mm3	326.05±50.8	307.04±54.28	0.2169
EDV, mm3	554.16±51.3	558.37±85.04	0.9391
SV, mm3	228.11±18.66	251.34±34.31	0.6161
LV mass, mg	723.64±23.47	765.52±28.9	0.1961
EF, %	43.25±5.2	46±3.4	0.5593

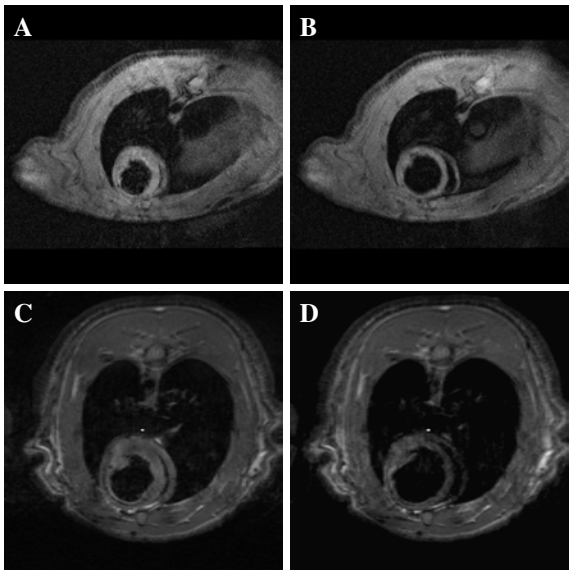

Figure 1. Representative MR images of the same animal (rat, 4 weeks after infarction) at end-systole (left) and end-diastole (right) acquired on Philips 3T Achieva human whole body scanner (A, B) and 4.7T Varian MR scanner (C, D). As a side note: the difference in chest shape is caused by difference in the coil shapes: custom-made coil for 4.7T is round cylinder with diameter of 5 cm; wrist coil for 3T Philips scanner has much larger diameter than rat body size, so custom-made plastic holder has been used for small animal imaging on 3T scanner.

Conclusion

This study showed that it is feasible to evaluate rat cardiac function *in vivo* using human clinical scale whole body scanner. Cardiac MRI protocol for non-invasive rodent imaging on Philips 3T Achieva MR scanner has been developed. With an optimized protocol, the measurements of cardiac morphology and function can be compatible between a specialized animal and a clinical human MR scanner.

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References

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