Chronic Myocardial Infarctions can be Reliably Characterized using Contrast-Free T1 Mapping at 3T

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Target Audience – Scientists and clinicians studying myocardial infarction

Purpose – Late Gadolinium Enhancement (LGE) Cardiovascular Magnetic Resonance (CMR) imaging is a powerful method to characterize myocardial infarctions (MIs). However, the requisite gadolinium infusion is contra-indicated in nearly 40% of the MI patients who also suffer from end-stage kidney disease. In this study, we tested the hypothesis whether contrast-freeT_1 maps at 3T can detect chronic MIs with high diagnostic accuracy relative to LGE images.

Methods – *CMR Protocol:* Canines (n=29) were subjected to 3 hours of full LAD occlusion followed by reperfusion. CMR was performed at 7 days (*acute, AMI*) and 4 months (*chronic, CMI*) post-MI on 19 canines at 3T and 10 canines at 1.5T. ECG-triggered breath-held 2D contrast-free T_1 maps (MOLLI; 8 TIs with 2 inversion blocks of 3+5 images; minimum TI=110ms; ΔTI=80ms; TR/TE=2.2/1.1ms), contrast-free T2 maps (T2-prepared SSFP; T2 preparation times = 0, 24 and 55ms; TR/TE=2.8/1.4ms) and LGE images (IR-prepared FLASH; optimal TI to null remote myocardium; TR/TE=3.5/1.75ms) of contiguous short-axis slices were acquired. Commonly used imaging parameters were slice thickness=6mm and in-plane resolution=1.3x1.3mm^2. *Image Analyses:* Remote myocardium was identified as the region showing no signal hyperintensity on LGE images. Infarcted myocardium was identified on both LGE images and T_1 maps using Mean + 5 standard deviations (SD) criterion relative to a reference ROI drawn in the remote myocardium. Infarct size (IS) was measured as the percentage of LV volume, as well as on a segmental basis using the AHA 17-segment model. Infarct transmurality (IT) was measured as the mean extent of the infarct along 100 equally-spaced radial chords drawn on each slice. *Histology:* Canines were sacrificed following month 4 CMR scan and the hearts were excised. TTC and Elastin Masson's Trichrome staining were performed. *Statistical Analyses:* T_1, T_2 and LGE signal intensity (LGE-SI) values were measured from remote and infarcted myocardium and compared. T_1 maps and LGE images were also compared for IS and IT measurements using paired t-test and Bland-Altman analysis. ROC analysis was performed to determine the diagnostic accuracy of T_1 maps for detecting MIs relative to LGE images.

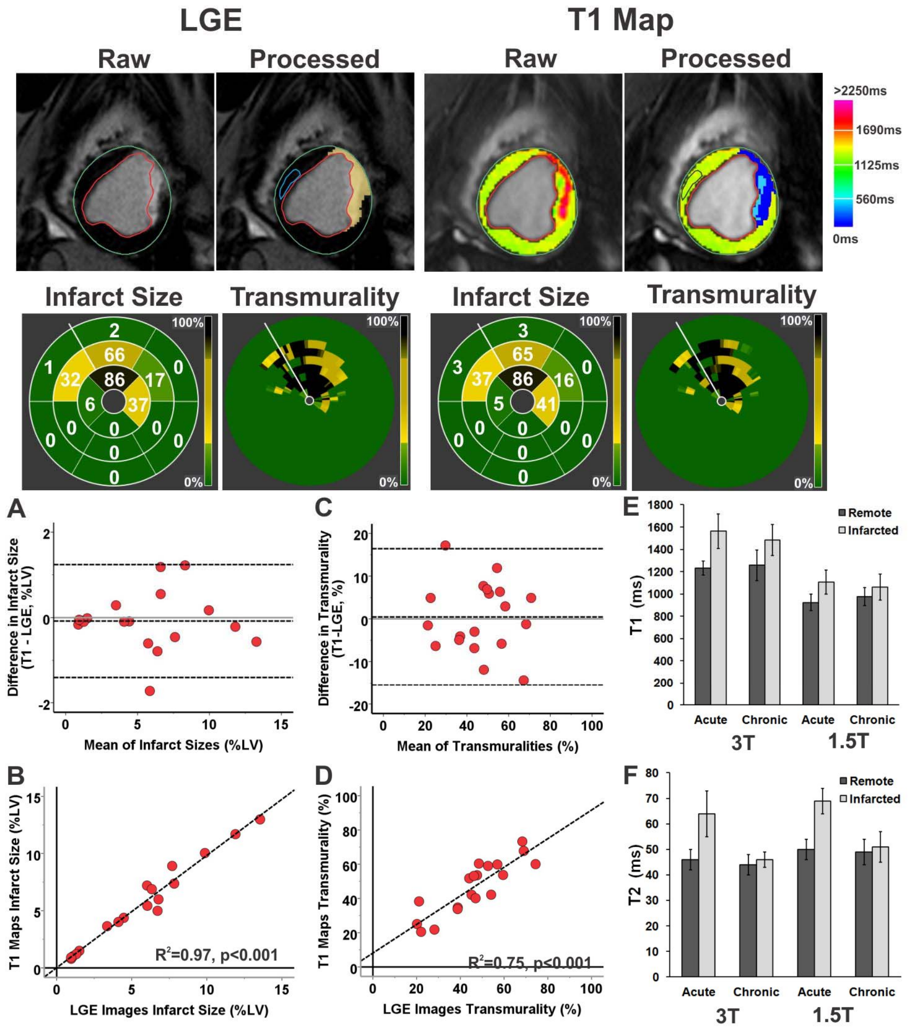

Figure 1: *Representative slice-matched LGE images and contrast-free T_1 maps acquired from a canine imaged at 3T (4 months post MI) are shown. Post-processed images delineating the MI territories using Mean+5SD criterion relative to remote myocardium are also shown. Hypointense core of iron deposition within hyperintense MI zone on T_1 maps was manually included in the analysis (highlighted light blue pixels on the processed images). AHA 17-segment bulls-eye plots showed excellent correlations between LGE images and T_1 maps for measuring infarct size (IS) and transmurality (IT). Strong agreement and correlation were observed between LGE images and T1 maps for measuring chronic IS (Bias = -0.08±0.68% (panel A) and R^2=0.97 (panel B)) and IT (Bias = 0.45±8.14% (panel C) and R^2=0.75 (panel D)) at 3T. Mean T_1 of infarcted myocardium was elevated relative to remote myocardium in AMI and CMI at both 3T and 1.5T (panel E). Mean T_2 of infarcted myocardium was elevated relative of remote myocardium in AMI at 3T and 1.5T (panel F). T_2 values of infarcted myocardium in CMI returned to baseline levels at 3T and 1.5T.*

Results – At 3T, T_1 maps showed no difference in IS and IT relative to LGE images in CMI (IS: 5.6±3.7% vs. 5.5±3.7%, p=0.61 and IT: 44±15% vs. 46±15%, p=0.81), but overestimated IS and IT relative to LGE images in AMI (IS: 13.3±8.4% vs. 11.6±6.8%, p=0.007 and IT: 64±19% vs. 56±17%, p=0.007). At 1.5T, T_1 maps underestimated IS and IT relative to LGE images in AMI (IS: 9.4±5.6% vs. 15.5±9.4%, p<0.001 and IT: 59±5% vs. 76±6%, p<0.001) and CMI (IS: 2.1±1.2% vs. 4.8±1.8%, p<0.001 and IT: 47±7% vs. 66±9%, p<0.001). Relative to the remote territories, T_1 of the infarcted myocardium was elevated in AMI (3T: p<0.001; 1.5T: p<0.001) and CMI (3T: p<0.001; 1.5T: p=0.037). T_2 of the infarcted myocardium was elevated in AMI (p<0.001 at both 3T and 1.5T), but not in CMI (3T: p=0.19, 1.5T: p=0.55) indicating that myocardial edema resolved at 4 months post-MI. Histology showed extensive replacement fibrosis within the CMI territories. CMI detection sensitivity and specificity of T_1 CMR were 95% and 97% respectively at 3T, and 58% and 78% respectively at 1.5T.

Conclusions – Contrast-free T_1 maps can reliably determine the location, size and transmurality of CMIs at 3T. Field-strength dependent native T_1 elongations of replacement fibrosis within CMIs may explain the observed sensitivity differences between 1.5T and 3T.