

Comparisons of Canine ECV Measurements by CMR at 3T: IR- vs. SR-based Cardiac T1 Mapping and Bolus Injection vs. Slow Infusion of Contrast Agent

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Introduction: Diffuse cardiac fibrosis is a marker of adverse left ventricular structural remodeling in a variety of cardiomyopathies¹. CMR is the only proven non-invasive modality for quantifying diffuse cardiac fibrosis. Both post-contrast cardiac T1 and myocardial extracellular volume (ECV) fraction, derived from hematocrit and pre- and post-contrast cardiac and blood T1 measurements, have been correlated with interstitial fibrosis burden. Despite the growing utilization of post-contrast cardiac T1 and ECV in the field of CMR for assessment of diffuse fibrosis, systematic studies investigating the nuance of different cardiac T1 mapping methods and contrast agent administration protocols are largely lacking. We sought to investigate two technical aspects – pulse sequence type and contrast agent administration protocol which may influence the accuracy of cardiac fibrosis assessment – in well controlled canine experiments at 3T. In the first experiment, we sought to compare ECV measurements between inversion-recovery (IR)-based MOLLI² and saturation-recovery (SR)-based arrhythmia-insensitive rapid (AIR) cardiac T1 mapping³ during steady-state equilibrium of contrast agent. In the second experiment, we sought to compare canine ECV measurements derived from AIR cardiac T1 mapping between bolus and slow infusion protocols^{4,5}.

Methods: A total of eighteen mongrel dogs with normal myocardium were imaged at 3T MR scanner (Verio, Siemens). For experiment 1 (MOLLI vs. AIR cardiac T1 mapping), cardiac T1 maps were acquired in a mid-ventricular short-axis plane in 16 dogs using both AIR and MOLLI cardiac T1 mapping pulse sequences at baseline and during equilibrium of Gd-BOPTA (Multihance; ~45 minutes after slow infusion at 0.002 mmol/kg/min). For experiment 2 (bolus vs. equilibrium), AIR cardiac T1 mappings were acquired in 18 dogs at baseline, exactly 15 min after a bolus injection of Gd-BOPTA (0.15 mmol/kg), and equilibrium. Both AIR and MOLLI acquisitions with b-SSFP readout were performed with the following relevant imaging parameters: spatial resolution = 1.4mm x 1.4mm x 7.0mm, temporal resolution = 217 ms, flip angle = 35°. Blood samples were drawn during MRI for hematocrit calculation. Epi- and endo-cardial contours and left ventricular blood pool were manually segmented to calculate their respective T1 and ECV values. Bland-Altman analysis was performed to assess data agreement.

Results: Figure 1 shows representative AIR and MOLLI cardiac T1 maps which exhibit similarly high image quality, but different T1 values, except for post-contrast blood. For experiment 1, in 16 dogs with mean heart rate = 100.2 ± 19.3 bpm, compared with MOLLI, AIR yielded higher T1 measurements (Fig. 2A, mean difference = 185 ms) and lower ECV measurements (Fig. 2B, mean difference = -1.8%, which corresponds to 8.6% of mean ECV of 21.0%). For experiment 2, in 18 dogs with mean heart rate = 96.5 ± 16.4 bpm, ECV measurements derived from the two different injection protocols agreed fairly well (Fig. 2C, mean difference = 1.1%, which corresponds to 5.3% of mean ECV of 21.3%).

Discussion: Our study demonstrates that IR- and SR-based cardiac T1 mapping pulse sequences yield significantly different cardiac T1 and ECV measurements, suggesting that CMR researchers must be careful when translating published values into their own studies. This study also demonstrates that contrast agent kinetics between humans and canines may be different and that 15 min after contrast agent administration may not be dynamic equilibrium in canine. This implies that CMR researchers must be careful when translating clinical late gadolinium enhancement protocols into pre-clinical studies.

References:

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3. Fitts M et al. *MRM* 2013;70:1274-82.
4. Schelbert EB et al. *JCMR* 2011;13:16.
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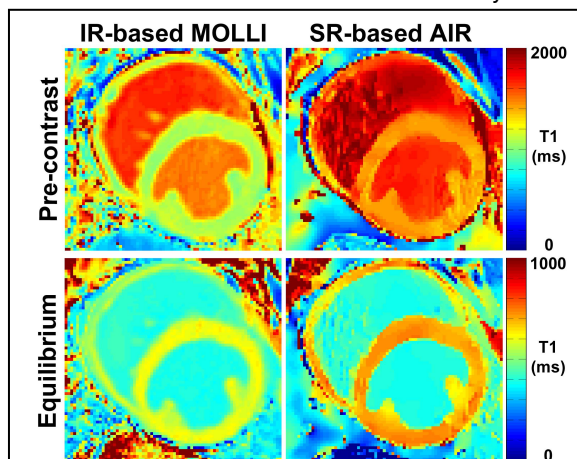


Figure 1. Example of IR-based MOLLI and SR-based AIR cardiac T1 maps in one animal acquired at baseline and during the equilibrium of Gd-BOPTA.

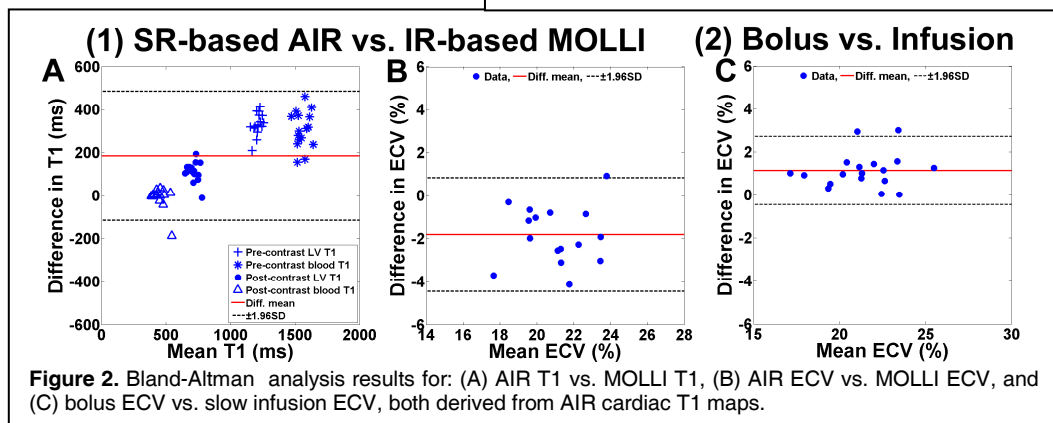


Figure 2. Bland-Altman analysis results for: (A) AIR T1 vs. MOLLI T1, (B) AIR ECV vs. MOLLI ECV, and (C) bolus ECV vs. slow infusion ECV, both derived from AIR cardiac T1 maps.