Free-breathing T1 Mapping MRI for Quantification of Myocardial T1 Pre and Post Contrast in Swine with Non-ischemic Heart Failure

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Introduction: Dilated cardiomyopathy is the most common type of non-ischemic heart failure, with persistent tachycardia being a common cause [1, 2]. The degree of myocardial fibrosis is thought to play a critical role in determining a patient's risk for sudden cardiac death. Cardiac T_1 mapping MRI enables myocardial signal quantification on a standard scale [3, 4]. The purpose of this study was to investigate a new free-breathing T_1 mapping pulse sequence to quantify myocardial T_1 changes in a tachycardia-induced heart failure swine model and to compare the T_1 mapping values to histological sections.

Methods: After obtaining IACUC approval, Yorkshire swine (N=9) were implanted with pacemakers and paced for 3 to 5 weeks at 200 beats per minute. Each animal was scanned in a 1.5 T MRI scanner (GE Signa, Waukesha, WI) at baseline (non-paced pacemaker in situ) and then at heart failure (N=6) (confirmed by echocardiography, with pacer turned off).

For the T_1 mapping, a Modified Look-Locker with Saturation Recovery SSFP sequence [5] (TE/TR 1.9/4.3ms, 45° FA, 256x160, 3 NEX, 20 VPS, 8mm slice, with 1-2 min free breathing) with three Look-Locker imaging blocks (2, 2, and 6 heartbeats respectively). The sequences starts with an initial TI of 50 ms, then adds TI increments of 40 ms (e.g. if the heart rate is 100 bpm (RR interval is 600ms), thus acquiring ten TIs of 50, 90, 130, 650, 690, 730, 1330, 1930, 2530, and 3130ms (50, 50+40, 50+2x40, 50+RR, 50+40+RR, 50+40x2 +RR, 50+40x2 +2xRR, 50+40x2 +3xRR,50+40x2 +4xRR, 50+40x2 +5xRR)). SSFP imaging was performed at each of the TI times with the following parameters: TE/TR 1.9/4.3ms, 45° flip angle, 256x160matrix, 3 NEX, 20 VPS, 8mm slice thickness, with 1-2 min free breathing scan duration. T_1 mapping sequences were performed before contrast, as well as at 5 and 12 minutes post intravenous administration of a 0.2 mmol/kg dose of gadolinium (Gd)-chelate contrast agent (Gadoteridol). Myocardial delayed enhancement sequences were acquired between 6 and 12 minutes post-contrast. The images were then post-processed using specially designed software.

Immediately post-euthanasia, myocardial tissue was collected from septum and left ventricular free wall and then was fixed in 10% formalin, embedded in paraffin, and cut into 5 µm sections using standard methods. Slides were stained using Accustain Masson Trichrome Blue. Ten images per tissue slide were captured with a Nikon Eclipse 80i microscope with digital DXM 12000c camera and analyzed using Nikon NIS Elements SW, vs. 3.0 (Nikon Instruments Inc., Melville, New York). Descriptive statistics performed using SPSS Statistical Software, v 16, (SPSS Inc., Chicago, IL).

Results: All baseline and all heart failure myocardial delayed enhancement images were negative. Baseline ejection fractions were 45 ± 4% and for the heart failure group, 14 ±7%. The mean T_1 value for the pre-contrast T_1 mapping sequence was 960 ±96 ms at baseline; and for the heart failure group, 726 ±94 ms, (Paired t-test, N= 6, p = .020). The 5 min post contrast T_1 value for the baseline pigs was 546 ±180 ms; and 300 ±171 ms, for the heart failure group (p = .005). The 12 min post contrast T_1 value for the baseline pigs was 509 ±129 ms; and 295 ±89 ms, for the heart failure group (N = 5, p = .060). Histological analysis showed an average of 0.88% fibrosis for the control animals and 2.60% (p < .01) for the heart failure animals.

Table 1. Statistical results for T_1 mapping using paired T-tests. Pre contrast and 5 minute post comparisons had 6 animals; the 12 minute post only had 5 animals.

Acquisition Period	Baseline T1 Mapping	Heart Failure T1 Mapping	Paired T-tests 2-tailed Sig. (.05)
Pre Contrast	960 ±96 ms	726 ±94 ms	p = .020
5 Min Post Contrast	546 ±180 ms	300 ±171 ms	p= .005
12 Min Post Contrast	509 ±129 ms	295 ±89 ms	p = .060

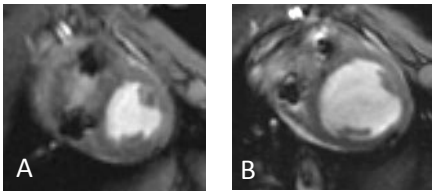

Figure 1. 2D Cine SSFP End Systolic Images at baseline (A), and heart failure (B).

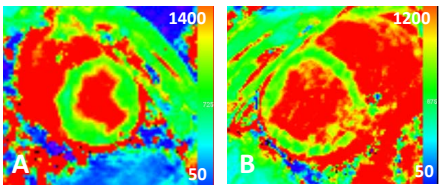

Figure 2. Short axis T1 maps acquired pre-contrast. Baseline map (A) has a higher range of values, 50-1400 ms, than the heart failure map (B) 50-1200 ms.

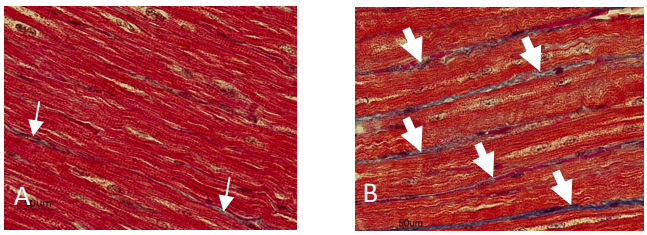

Figure 3. Myocardium stained with Masson Trichrome Blue. Myocytes are red and collagen is blue. A small amount of structural collagen (small arrow) is seen in the control tissue (A), whereas, considerably more fibrotic (collagen) blue streaks (bold arrows) are seen in heart failure (B).

Discussion: This study demonstrates that free breathing T_1 mapping is a promising technique to quantify myocardial changes in heart failure and myocardial T_1 values are significantly reduced in heart failure, with or without Gd-chelate contrast agent. The changes in myocardial T_1 values appear to reflect an increase in collagen in the heart failure myocardium as compared to control animals. In addition, myocardial changes on T_1 mapping appear to pre-date changes seen on MDE. More research is needed to further correlate the T1 mapping values with the degree of change in collagen levels in the myocardium and to improve the free breathing T_1 mapping technique.

References:

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