Improved Arrhythmia-Insensitive-Rapid (AIR) cardiac T_1 Mapping with Pulse Sequence Optimization: k-space Ordering and Flip Angle

Kyungpyo Hong[1,2] and Daniel Kim[1]

[1]UCAIR, Department of Radiology, University of Utah, Salt Lake City, Utah, United States, [2]Department of Bioengineering, University of Utah, Salt Lake City, Utah, United States

Purpose: Cardiac T_1 mapping is emerging as promising method for assessment of diffuse cardiac fibrosis. Recently developed arrhythmia-insensitive-rapid (AIR) cardiac T_1 mapping pulse sequence [1] is a promising method for imaging patients with rapid heart rates and/or arrhythmia. The original AIR, however, may produce image artifacts associated with eddy currents because it uses centric k-space ordering with balanced steady-state of free precession readout. The original AIR may also produce low precision because it acquires only two images. We sought to improve AIR cardiac T_1 mapping through k-space ordering and flip angle optimization.

Methods: *(Experiment 1: k-space ordering optimization)* In 6 subjects (5 patients and 1 volunteer, 3 cardiac views per subject), we compared the performance of AIR T_1 mapping using conventional centric and centric-paired [2] k-space orderings (Fig. 1) with previously used flip angle of 35° [1]. The k-space ordering that produced less image artifacts was then used throughout. *(Experiment 2: flip angle optimization)*. In 11 human subjects (4 volunteers and 7 patients), we performed AIR T_1 mapping in a mid-ventricular short-axis plane with flip angles ranging from 25-65° (10° steps), where 65° is the maximum value allowed within the specific absorption rate limit at 3T. This experiment was conducted with and without administration of contrast agent (0.15 mmol/kg of Multihance). *(Imaging Parameters)* We conducted the two experiments on a 3T (Siemens Verio) using the following imaging parameters: FOV = 340 x 255 mm^2, slice thickness = 8 mm, acquisition matrix = 192 x 144 (PE), TE = 1.1 ms, TR = 2.7 ms, receiver bandwidth = 930 Hz/pixel, readout duration = 217 ms, saturation-recovery time delay (TD) = 600 ms, breath-hold duration = 2-3 heart beats, acceleration factor (GRAPPA) = 1.8, and 30 dummy RF pulses with amplitude envelop in the shape of a Kaiser Bessel function. *(Image Analysis)* AIR cardiac T_1 maps were generated using the Bloch equation describing T_1 relaxation in saturation recovery [1]. Left ventricular cavity and wall contours were drawn carefully to avoid partial volume averaging effects. For statistical analysis, to compare the T_1 values per measurement type, we used ANOVA to test for differences in mean T_1 between flip angles, and Bonferroni correction to compare each pair of groups. We performed also the intra-class correlation (ICC) analysis to evaluate the association of mean T_1 between flip angles.

Results: Figure 1 also shows AIR T_1 maps of a volunteer acquired with centric and centric-pair k-space orderings. In all 6 subjects (18 cardiac views), centric k-space ordering acquisitions yielded image artifacts arising from eddy currents, whereas centric-pair k-space ordering acquisitions suppressed image artifacts. Figure 2 shows native and post-contrast AIR T_1 maps of a patient acquired with flip angles ranging from 25-65°. These maps show decreased standard deviation with increasing flip angles, particularly for native T_1 maps. Figure 2 also shows plots of mean T_1 and standard deviation as a function of flip angle, for each of 4 different types of measurement. According to ANOVA, mean T_1 values were not different between flip angles ranging from 25-65° for any of the 4 types of measurement (native myocardial T_1, native blood T_1, post-contrast myocardial T_1, and post-contrast blood T_1). According to the ICC analysis, mean T_1 values were strongly correlated with correlation coefficient ≥ 0.95 for all measurement types.

Conclusion: With these two upgrades (centric-pair k-space orderings + flip angle = 55-65°), improved AIR cardiac T_1 mapping is likely to yield better quality data than original AIR T_1 mapping in pre-clinical and clinical applications.

References: **[1]** Fitts M, et al. Magn Reson Med. 2013;70(5):1274-82. **[2]** Bieri O, et al. Magn Reson Med. 2005;54:129-137. **Funding:** NIH (HL116895-01A1), American Heart Association (14GRNT18350028).

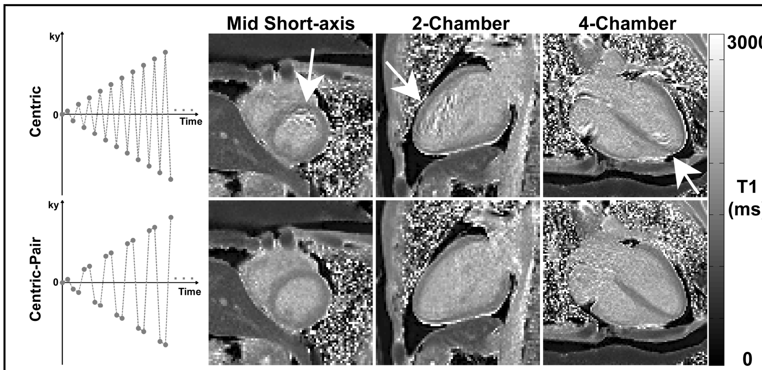

Figure 1. Centric (top row) and centric-pair k-space orderings. Representative T_1 maps acquired using centric and centric-pair orderings (columns 2-4).

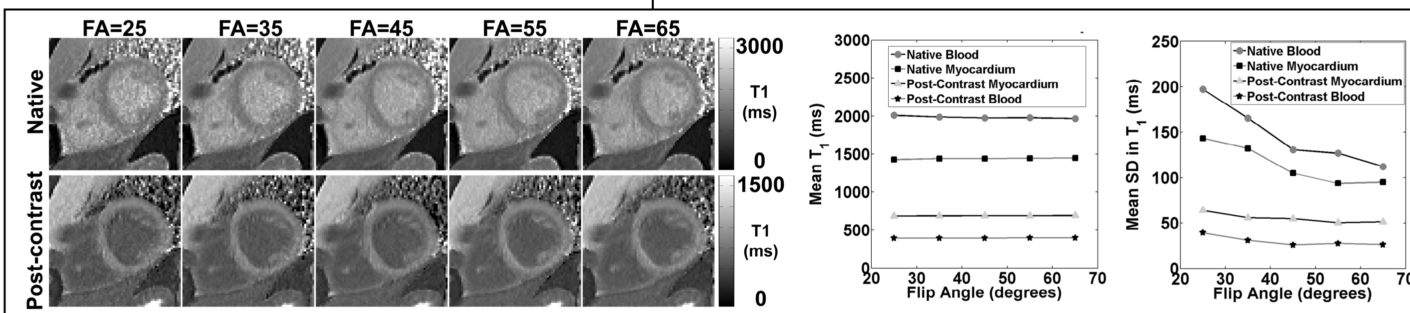

Figure 2. Native (top row) and post-contrast (bottom row) T_1 maps with flip angles ranging from 25-65° as shown. Plots of mean T_1 and standard deviation (SD) in T_1 as a function of flip angle per measurement type as shown.