Intrinsic motion correction for radial cardiac T_2 mapping through alternating T_2 preparation duration

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Introduction: T_2 mapping through variation of the T_2 preparation (T_2Prep) duration has been increasingly used to detect and quantify cardiac edema in response to myocardial injury[1]. However, if images with incremental T_2Prep duration are acquired in a sequential fashion (Fig.1a), irregular breathing patterns and heart rates may adversely affect the quality of the T_2 maps due to misalignment of the source images. A logical alternative is then to acquire all images in an alternating manner (Fig.1b), where the T_2Prep duration changes cyclically from one heartbeat to the next. Combined with a radial signal readout, this may minimize the vulnerability to respiratory or RR variability. We therefore simulated, implemented and tested the use of an alternating magnetization preparation approach to T_2 mapping.

Methods: A navigator-gated ECG-triggered radial gradient-recalled-echo pulse sequence (20 lines per heartbeat, ECG trigger every 3 heartbeats) was implemented to obtain source images for the T_2 maps[2], with the possibility to apply the T_2Prep durations of 60/30/0ms in both an alternating and sequential manner. The sequential T_2Prep source images were co registered before T_2 fitting[3], while the alternating T_2Prep images were not. Bloch equation simulations were performed in order to estimate the longitudinal magnetization residual due to T_1 relaxation[2], as well as the accuracy over a range of heart rates. The sequences were validated in agar-$NiCl_2$ phantoms at 3T (12-channel surface coil array, on a Magnetom Trio, Siemens, Erlangen, Germany) by comparing the resulting T_2 maps to gold-standard spin-echo (SE) T_2 maps. A mid-ventricular short-axis T_2 map was then acquired with both (alternating and cyclical T_2Prep) pulse sequences in 9 healthy adult volunteers. The total myocardial surface area and AHA-standard[4] segmental left ventricular (LV) wall thickness were measured in the T_2 maps, after which a paired Student's t-test was applied to detect differences.

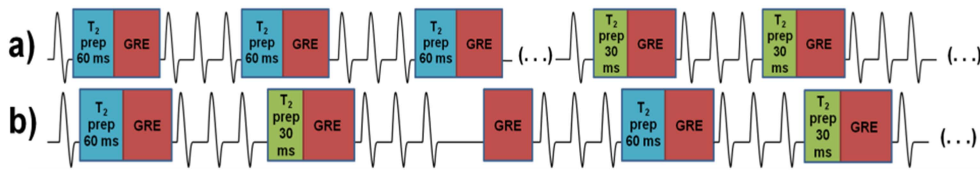

***Figure 1** - **a)** Schematic of the conventional sequential acquisition pattern. The T_2Prep duration is changed only after acquisition of an image. This approach may be more vulnerable to irregular heart rates or respiration patterns. **b)** Schematic of the alternating acquisition pattern. The T_2Prep duration is alternated between 60, 30 and 0 (no T_2Prep) ms from heartbeat to heartbeat. All images are acquired in an interleaved fashion and on average experience similar motion.*

Results: The Bloch equation simulations demonstrated that the T_2 value in the alternating method was most accurately fitted with a longitudinal magnetization residual of 0.13 and that it was as robust to heart rate variation as its sequential counterpart: ~3.4ms vs. ~2.4ms variation in fitted T_2 value between 40 and 90bpm for the alternating and sequential methods, respectively. Its accuracy was confirmed in the phantoms: T_2=45.4±0.7ms for the alternating method vs. 45.3±0.7ms for the sequential method and 45.1±0.7ms for the spin-echo gold standard. The myocardial surface area was larger in the alternated T_2 maps of the volunteers (8.4±1.8cm^2 vs. 7.5±1.8cm^2, $p<0.001$) (Fig.2), while the average midventricular T_2 value slightly differed between the alternated and sequential methods (T_2=36.5±2.2ms alternated vs. 39.1±2.7ms sequential, $p<0.001$). The LV wall thickness measurements demonstrated that when the alternating method was used, the lateral segments had a higher thickness increase than the septal segments (Fig. 2c). The average thickness increase when comparing the alternating to the sequential method was 12±13% $p<0.01$.

Discussion: The alternating method demonstrated a larger LV surface area and LV wall thickness than the sequential method, while their T_2 fitting robustness was similar. The larger LV wall surface area and thickness in the alternating T_2 maps may be explained by the intrinsic source image alignment of this method: the source images obtained from the alternating method are less subject to transient changes of the end-expiratory position or RR changes during the scan. In contrast, and for a sequential acquisition, such transient changes inevitably lead to misalignment of the source images and ultimately also a smaller number of pixels that are available for analysis.

Conclusions: We successfully implemented and tested a T_2 mapping methodology in which the T_2 preparation is alternated. The *in vivo* T_2 maps demonstrate that this alternating method results in a better registration of the source images, which in turn results in a larger myocardial thickness and the availability of a larger number of pixels that can be exploited for T_2 mapping. This may allow for more accurate T_2 quantification.

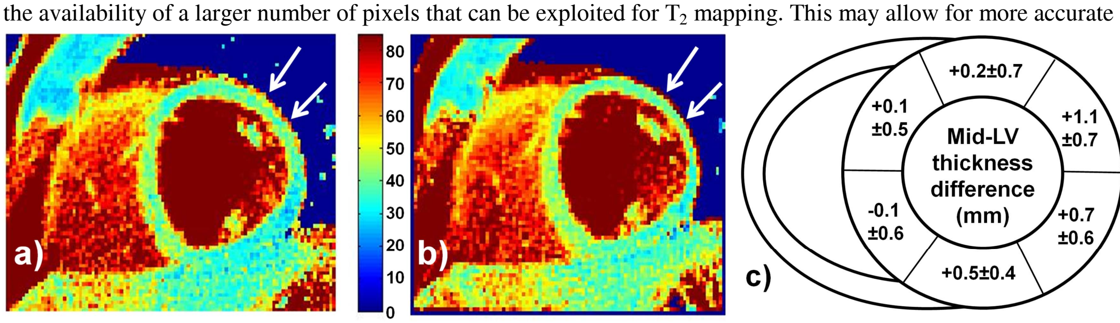

***Figure 2 – a) and b)** T_2 map of volunteer acquired with the alternating (**a**) and sequential (**b**) method. Note that consistent with the quantitative findings, the antero-lateral myocardium is thicker when acquired with the alternating method (arrows). **c)** Myocardial LV thickness increase (in mm) when using the alternating method.*

References: 1. Giri et al., J Cardiov Magn Reson 2009;11:56, **2.** van Heeswijk et al., JACC Cardiov Imag 2012; 5(12):1231, **3.** Giri et al., Magn Reson Med 2012; 68(5):1570, **4.** Cerqueira et al.; Circulation 2002;105:539