Intrinsic motion correction for radial cardiac T2 mapping through alternating T2 preparation duration
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Introduction: T2 mapping through variation of the T2 preparation (T2Prep) duration has been increasingly used to detect and quantify cardiac edema in response to myocardial injury. However, if images with incremental T2Prep duration are acquired in a sequential fashion (Fig.1a), irregular breathing patterns and heart rates may adversely affect the quality of the T2 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 T2Prep 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 T2 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 T2 maps, with the possibility to apply the T2Prep durations of 60/30/0ms in both an alternating and sequential manner. The sequential T2Prep source images were co-registered before T2 fitting, while the alternating T2Prep images were not. Bloch equation simulations were performed in order to estimate the longitudinal magnetization residual due to T1 relaxation, as well as the accuracy over a range of heart rates. The sequences were validated in agar-NiCl2 phantoms at 3T (12-channel surface coil array, on a Magnetom Trio, Siemens, Erlangen, Germany) by comparing the resulting T2 maps to gold-standard spin-echo (SE) T2 maps. A mid-ventricular short-axis T2 map was then acquired with both (alternating and cyclical T2Prep) 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 T2 maps, after which a paired Student’s t-test was applied to detect differences.

Results: The Bloch equation simulations demonstrated that the T2 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 T2 value between 40 and 90bpm for the alternating and sequential methods, respectively. Its accuracy was confirmed in the phantoms: T2 = 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 alternating T2 maps of the volunteers (8.4±1.8cm² vs. 7.5±1.8cm², p<0.001) (Fig.2a), while the average midventricular T2 value slightly differed between the alternating and sequential methods (T2 = 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 T2 fitting robustness was similar. The larger LV wall surface area and thickness in the alternating T2 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, for a sequential acquisition, such transient changes 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 T2 mapping methodology in which the T2 preparation is alternated. The in vivo T2 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 T2 mapping. This may allow for more accurate T2 quantification.


Figure 1 - a) Schematic of the conventional sequential acquisition pattern. The T2Prep 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 T2Prep duration is alternated between 60, 30 and 0 (no T2Prep) ms from heartbeat to heartbeat. All images are acquired in an interleaved fashion and on average experience similar motion.

Figure 2 – a) and b) T2 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.