Reducing the Sensitivity to Respiratory Motion of Modified Look-Locker with Saturation Recovery for Cardiac T1 Mapping

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Introduction

Ongoing challenges in quantitative myocardial imaging are motion artifacts caused by respiratory and cardiac motion. We have previously presented a modified Look-Locker with saturation recovery (MLLSR) sequence for cardiac T1 mapping [1,2]. To address cardiac motion, data acquisition is limited to quiescent periods of the cardiac cycle necessitating a segmented method. However, respiratory motion resulting from failed breath holding remains an issue. If a subject fails to maintain a consistent breath hold throughout the entire scan the acquired K-space data is not consistent across segments and this can result in motion artifacts. A new scheme of segment arrangement is proposed in this context. Phantom and human studies were evaluated with the two schemes.

Methods

For comparison, a baseline MLLSR sequence that acquires eight TI times with 2 segments per TI time was used. The first scheme uses a typical segmented approach where the first eight heartbeats are used to acquire the first segment (Figure 1a), and last eight heartbeats to acquire the second segment. The second scheme (Figure 1b) acquires the two segments for each TI time in consecutive heartbeats. The Look-Locker blocks use 2, 2, and 4 heartbeats per block as illustrated in Figure 1. For example if the heart rate is 60 bpm, then two segments with 16 heartbeats are acquired at TIs of 100-3300msec. An SSFP data acquisition scheme was performed with the following parameters: TE/TR 1.7/3.9ms, 45° flip angle, 256x160matrix, 0.5 NEX, 38 VPS, 8mm slice thickness, 32x28cm FOV. Phantom validation measurements were performed using a set of Gadolinium (Gd)-chelate contrast dilution phantoms with T1s ranging from 100 to 1700ms. To simulate a failed breath hold, periodic scanner table motion was initiated halfway through scanning. A clinical patient with normal myocardial function was also assessed using the two different segment schemes. The patient was instructed to hold their breath as long as possible.

Results

The phantom study illustrated the impact of motion that occurs part way through the scan. Using the first acquisition scheme, motion occurs during the acquisition of the second segment for all TI times, resulting in motion artifacts in all 8 TI images (Figure2a). Using the second scheme complete image data was acquired for 4 of the 8 TI times prior to the motion. This results in 4 images that are uncorrupted by motion and 4 with motion artifacts (Figure 2b). Note that due to the interleaved nature of the TI sampling times, uncorrupted data across a wide range of TI times is obtained. In the patient study, despite attempting to be fully compliant with the full breath hold time we are able to see residual motion artifacts using the first sampling scheme (Figure 3a). With the second scheme motion artifacts are effectively suppressed (Figure 3b). The corresponding quantitative T1 maps are also shown in Figure 3. Note that although the second acquisition scheme reduces motion artifacts it does so at the cost of bulk translational motion in the TI times that are encoded during respiratory motion. Thus the T1 maps produced using the second scheme can demonstrate some additional blurring due to the bulk motion of the heart. However, if the bulk motion is too large this second sampling scheme allows one to drop individual, corrupted, TI images from the quantitative T1 fitting procedure as needed or to apply registration methods to realign the images before processing.

Conclusions

Two different segmented acquisition schemes applied to a myocardial T1 mapping sequence are compared in both phantom and human studies. The trade-off between the two algorithms are consistency in K-space sampling to reduce motion artifacts versus effects of cardiac position variation in T1 mapping accuracy.

References [1] T. Song, et al, ISMRM 2009, pp483. [2] G. Slavin, et al, SCMR 2007.

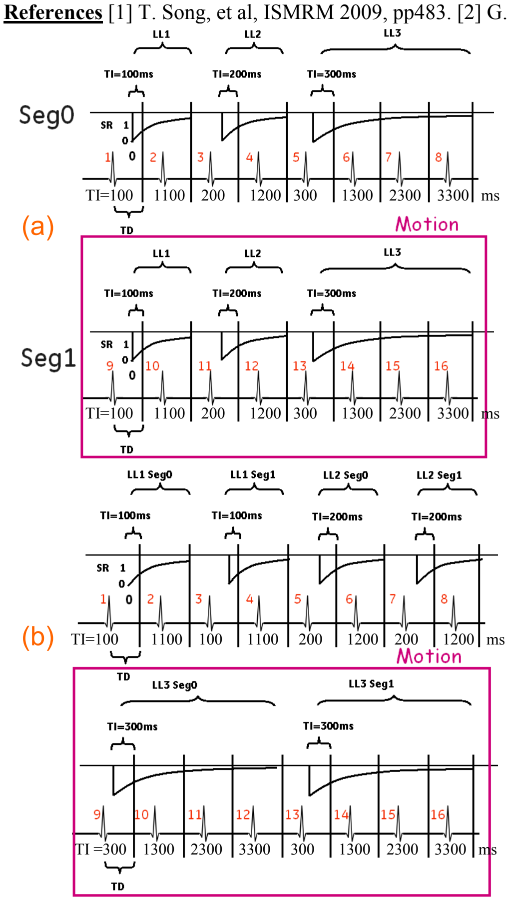

Figure1, Sequence diagrams of two schemes.

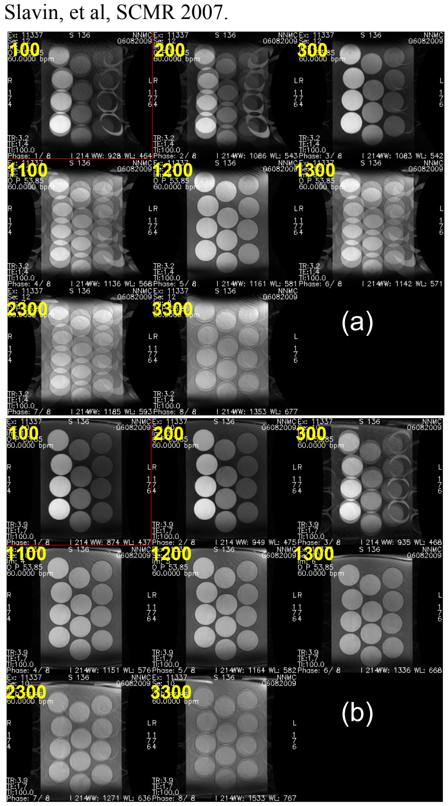

Figure2, Phantom experiment using two schemes with disturbed motion in the last eight heartbeats. TI times (ms) for each image are displayed.

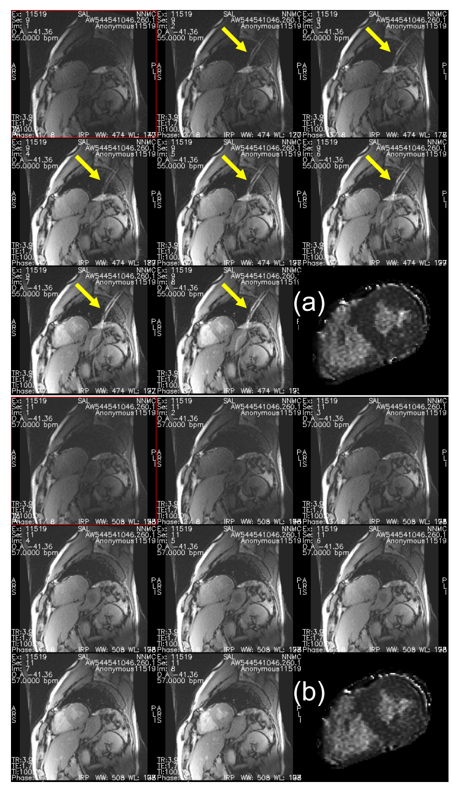

Figure3, T1 mapping in a patient using the two schemes. Image artifact from slight residual respiratory motion can be seen in (a) and some slight additional blurring from residual respiratory motion can be seen in (b).