A Fast Myocardial T1 mapping method compatible to MOLLI

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Target audience: MR physicists and pulse sequence engineers working on cardiac imaging.

Purpose

T1 mapping of the heart provides a quantitative method to visualize and evaluate structure variances[1]. Quantification of the pre- and post-contrast T1 change in late gadolinium enhancement allows the assessment of cardiac disease status [2,3]. For cardiac T1 mapping, modified Look-Locker inversion-recovery (MOLLI) has been demonstrated reliable and been widely used in clinical applications[4]. However, the MOLLI protocol requires patients to hold their breath for about seventeen heartbeats. This requirement could be an obstacle to apply MOLLI on patients unable to perform long voluntary breath-hold. In this study, inspired by a recently study presenting a fast 3D whole brain T1 mapping[5], we proposed a rapid cardiac T1 mapping method where only three heartbeats from MOLLI data are needed.

Methods

The rapid cardiac T1 mapping is based on the "ratio" method which was previously reported to achieve 3D whole brain T1 mapping[5]. It requires three gradient-echo images to sample the relaxation curve after an inversion pulse. The first and second images were divided by third image to generate two ratio images in which the B1 inhomogeneity is compensated. The relaxation model of these two ratio images is derived according to the Bloch's equations with the parameters of T1, delay times, flip-angle and efficiency of inversion-recovery pulse. A Levenberg-Marquardt least-square curve fitting with the relaxation model and the two ratio images was employed to generate T1 mapping. The data acquisition scheme is fully compatible to the MOLLI sequence with 3-3-5 acquisition scheme[4]. We used the first three images obtained in the MOLLI sequence to perform ratio-based T1 calculation. This method is termed Ratio-T1 method hereafter.

Six healthy participants (males, age: 23±2.45) underwent T1 mapping study with a 3.0 Tesla scanner (Siemens, Tim Trio) after providing informed consent. We performed MOLLI imaging using the following parameters: TR/TE: 2.72/1.3 ms, matrix: 256×208, flip angle: 8°, 2-fold GRAPPA acceleration, four slice orientations: basal, mid-cavity, apical and two-chamber, measurement number: 3, MOLLI acquisition scheme: 3-3-5. The in vivo experiment totally acquired 72 MOLLI data sets (6 participants x 4 slices x 3 repeats). The 3-3-5 scheme acquired 11 images in each data set. We then reconstructed two T1 maps, a MOLLI-T1 map and a Ratio-T1 map using each data set. A MOLLI-T1-map was generated with all 11 images of each data set using the original MOLLI T1 mapping algorithm[5]. A Ratio-T1-map was produced with the first three images of each data set using the proposed ratio-based algorithm. We manually selected 19 regions of interests (ROIs) on 4 slices, including one liver ROI, one ROI covering blood pool in the left ventricle (LV), 17 myocardium segments using the AHA-17 standard[6]. We then calculated the average T1 value in each ROI. This procedure generates 342 T1 values (6 participants x19 ROIs x 3 repeats) for each T1 reconstruction method (i.e., MOLLI and Ratio-T1).

Results

Figure 1 displays the linear regression between T1 values obtained using Ratio-T1 and MOLLI. The regression analysis reveals high correlation between two methods (slope: 1.389, bias: -227.13, r^2=0.989). Figure 2 shows T1 maps (left-column: basal, right-column: apical) calculated using Ratio-T1 (Figs. 2a and 2b), Ratio-T1 adjusted with the regression model (Figs. 2c and 2d), and MOLLI (Figs. 2e and 2f). Using the MOLLI T1 maps as reference standards, the Ratio-T1 maps shows overestimation on the T1 values whereas the adjusted Ratio-T1 maps exhibits visually similar to the MOLLI T1 maps. We observed that the sharpness of the LV walls in Fig.2c (Ratio-T1) is slightly better that in Fig.2e (MOLLI). The reason of the sharpness discrepancies may be caused by the differences of acquisition durations of the two methods (Ratio-T1: 3 heart beats, MOLLI: 17 heart beats).

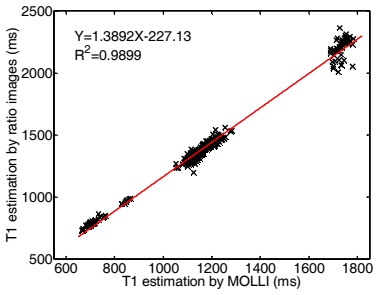

Fig. 1: Regression analysis of T1 values obtained using Ratio-T1 and MOLLI.

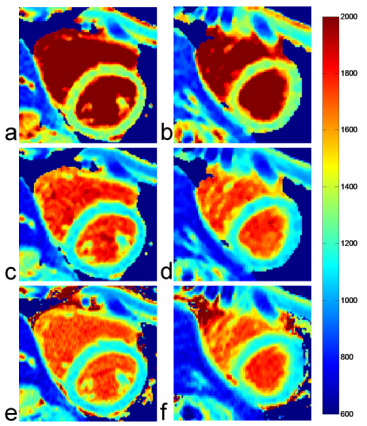

Fig. 2: The obtained T1 maps (basal: left column, apical: right column). (a,b) Ratio-T1 maps (c,d) model-adjusted Ratio-T1 maps (e,f) MOLLI T1 maps.

Discussion

This study attempts T1 mapping using only three samples of the relaxation curves. The proposed method is fully compatible to the original MOLLI sequence. To validate this method we acquired all 11 images using MOLLI sequence and reconstructed T1 maps using the Ratio-T1 method and the MOLLI method, which allows a direct comparison of T1 values obtained using the two methods. Although the results showed T1 overestimations when using the Ratio-T1 method, the T1 values obtained using two methods were highly correlated with good precision. The Ratio-T1 method has advantages when a patient fails to perform voluntary breath-hold during MOLLI image acquisition, particularly when through-plane motion precludes retrospective motion correction. Hence the Ratio-T1 method could be a plausible alternative without the need to modify the original MOLLI acquisition with either 5-3-3 or 5-3 schemes. The correlation result supports the possibility of quantifying the extracellular volume[2,3] (ECV) of the myocardium because ECV could be estimated using relative T1 values of the myocardium and the blood. A phantom study expanding the range of T1 regression analysis and patient studies to evaluate the diagnostic value of the Ratio-T1 method merits further studies. In conclusion, this study presented a T1 mapping algorithm requiring only the first three images acquired using the MOLLI sequence. It is suitable to acquire T1 maps from patients who cannot perform long voluntary breath-hold or to reconstruct MOLLI data sets with uncorrectable motion artifacts.

References

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