Free-breathing myocardial 3D T1 mapping using inversion time specific image-based respiratory navigators

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Introduction: Longitudinal relaxation time (T1) mapping is becoming an increasingly valuable tool in cardiovascular MR to diagnose a range of cardiomyopathies [1,2]. However, clinical T1 mapping scans have been largely limited to 2D breath-hold acquisitions with resulting restrictions in the achievable spatial resolution and signal-to-noise ratio. Free-breathing 3D T1 mapping has been proposed using respiratory motion correction by means of conventional diaphragmatic 1D navigation [3]. Recently, image-based navigation [4] has emerged as an alternative approach which allows for direct respiratory motion estimation of the heart instead of the diaphragm. However, its application to T1 mapping is challenging due the vastly different contrasts between images at different inversion times (TI), which may lead to navigator motion estimation errors if a single navigator reference is used for all TIs. In this work we evaluate a method for 3D T1 mapping using multiple TI specific respiratory image navigators.

Methods: The proposed T1 mapping sequence used a MOdified Look-Locker Inversion recovery (MOLLI) approach as shown in Figure 1a, with a 2-3 acquisition scheme (2 images acquired after the first inversion, 3 after the second). A pause of three heart beats was inserted before each inversion pulse to ensure full magnetization recovery. Two-dimensional image navigators (iNAV) were acquired for each k-space segment using the startup echoes of the bSSFP sequence [4]. To account for the differences in image contrast at different TI, iNAVs acquired at a certain TI were registered to a reference iNAV acquired in the first corresponding TI, as shown in Figure 1b. To ensure all reference iNAVs were acquired at the same end-expiratory position the first MOLLI cycle was acquired during a breath-hold, while subsequent inversion cycles were acquired during free breathing. With this approach, translational motion correction was performed in foot-head and left-right direction, and 100% scan efficiency was achieved. T1 maps were acquired in 7 healthy subjects using a 1.5T clinical scanner (Philips Healthcare, The Netherlands) covering the whole heart with a 2mm isotropic resolution and otherwise standard T1 mapping imaging parameters. In addition, 2D breath-held MOLLI images using a 5-3 acquisition scheme were acquired in a short-axis view.

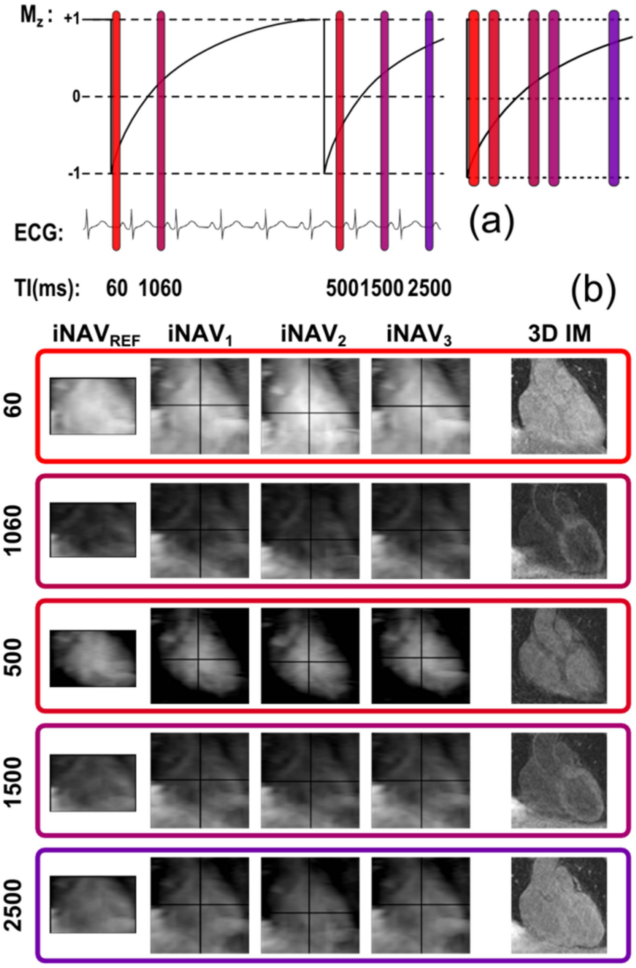

Figure 1. *3D T1 mapping using a 2-3 MOLLI scheme (a). Respiratory 2D image navigators (iNAV) for each inversion time (TI) with the corresponding motion corrected 3D image (3D IM) (b). The $iNAV_{REF}$ for each TI were acquired in the first MOLLI cycle of the scan during a breath-hold.*

Results: Images acquired with free-breathing 3D MOLLI are shown in Figure 2, including a short-axis 2D MOLLI. The mean ± standard deviation (SD) T1 values of myocardium and blood were 1018±22 ms and 1362±32 ms respectively, using the proposed method. The corresponding values for 2D breath-hold MOLLI were 975±35 and 1538±41 ms. The mean ± SD scan time of the 3D MOLLI scan was 9:48±0:20 minutes for the healthy subjects.

Discussion and Conclusion: In this work, we have demonstrated the feasibility of using an image-based respiratory motion correction technique to perform T1 mapping of the whole heart with isotropic resolution. T1 values of the myocardium for the proposed approach are in good agreement with the reference 2D MOLLI. The use of TI-specific reference iNAVs yields accurate registration between iNAVS for a certain TI, while the use of breath-holding to acquire the reference iNAVs ensures good co-registration between images at different TI.

References: [1] Ferreira, JACC 2013; [2] Puntmann, JACC 2013; [3] Weingartner, MRM 2014; [4] Henningsson, MRM 2012.

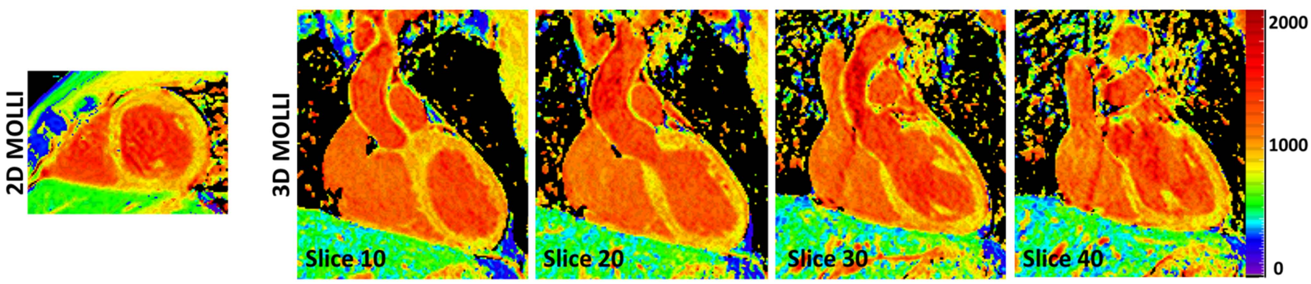

Figure 2. *T1 maps obtained in a healthy subject with 2D MOLLI in short axis, and proposed 3D MOLLI acquired in coronal orientation.*