Fast T2 mapping of the Heart from Highly Undersampled Radial FSE Data Using a Principal Component-Based Reconstruction Algorithm

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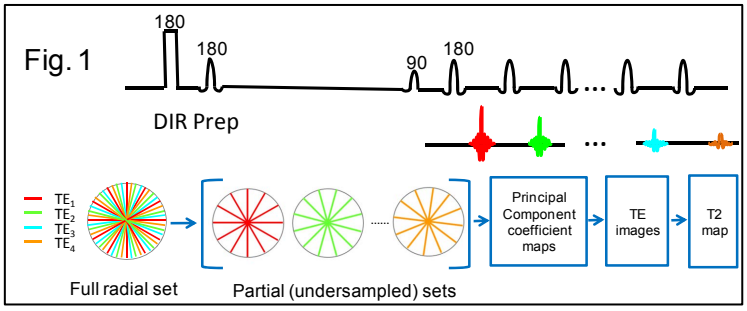
Introduction: T2-weighted imaging is an important modality in cardiac MRI and has been used for the diagnosis of a series of pathologies. Recently, several publications highlighted the higher diagnostic value of T2 based MRI techniques in patients with myocardial inflammation (1-2). As an alternative to conventional T2-weighted imaging, T2 mapping of the heart has recently being proposed (3,4). Because the acquisition of cardiac data are limited to a breath hold, there are trade-offs between spatial and temporal resolution in the acquisition of data for T2 mapping. Another complication in T2 mapping of the heart is motion. The latter affects the quality of the TE images used for T2 mapping and introduces data misregistration which precludes voxel-wise fitting of the data.

In this work we present a double inversion radial fast spin-echo (DIR-RADFSE) technique combined with a principal component based reconstruction algorithm recently developed for T2 estimation (5,6). The method provides motion insensitivity and high spatial and temporal resolution data for the reconstruction of T2 maps from data acquired in a single breath hold.

Technique As shown schematically in Fig. 1 in the DIR-RADFSE sequence data acquisition follows a double–inversion preparation period (for blood nulling) with data from all TE points (typically 16) collected on each TR period. After data from all TR's are acquired (~ 16 TRs) we have a full radial k-space data set. The full k-space data set is used to reconstruct a black-blood image with T2 contrast approximating the average TE. As shown in the figure, the full k-space data set is also partitioned into partial k-space sets. The partial sets are highly undersampled with ~ 16 radial lines per set. To reconstruct high resolution TE images and T2 maps from the undersampled data sets we use a principal component model-based reconstruction algorithm where the T2 decay model is linearized by principal component analysis (5,6). Penalty terms are enforced in the reconstruction to exploit the spatial and temporal sparsity of the TE images according to the compressed sensing theory. Compared to an echo sharing technique, previously developed for radial fast spin-echo data (7), the principal-component based reconstruction yields better T2 estimates for small structures and edges, thus it is better suited to evaluate the heart.



Methods: Data were acquired with gated DIR-RADFSE on a 1.5T GE scanner. A total of 256 radial views (256 readout points per view) were collected with ETL=16 to yield 16 highly undersampled TE data sets (16 radial lines per TE). The echo spacing was 9 ms to yield a TE coverage of 144 ms. TR = 1RR, receiver bandwidth = ±31.25 kHz, NEX=1, slice thickness 8 mm. Subjects were consented according to IRB regulations. The TE images were reconstructed jointly from all acquired data using a model-based iterative reconstruction algorithm. T2 maps were derived from the TE images by exponential fitting.

Results: Figure 2 shows three out of the sixteen TE images reconstructed from DIR-RADFSE data together with a colorized T2 map of the LV overlaid onto the anatomical image. The delayed enhancement (DE) images are also included. TE images and T2 maps are obtained from data acquired in a breath hold. The top row shows images of a subject with a history of LV dysfunction secondary to ischemic cardiomyopathy. There is an extensive inferior and infero-lateral area of myocardial scar seen on the DE images; this area (arrow) has a higher T2 than the rest of the myocardium. The bottom row shows images from a subject with hypertrophic cardiomyopathy and ventricular ectopy. There are areas of high signal intensity within the myocardium that are clearly seen in the TE images; these correspond to regions of high T2 (see T2 map) and are likely due to inflammatory changes in the myocardium. Of note, only small focal areas of hyperintensity are seen on DE images (most likely due to fibrosis), which is consistent with the fact that T2 imaging is more suitable for detecting inflammatory changes in the heart (1,2).

Conclusions: A DIR-RADFSE pulse sequence combined with a principal component based algorithm has been demonstrated for rapid T2 mapping of the heart. The method yields perfectly registered multiple high-resolution TE images and a T2 map from data acquired in a single breath hold. The method can be used for diagnosing changes in the myocardium related to inflammatory processes as well as other pathologies that affect the T2 relaxation properties of the heart. The technique can provide complementary information to DE imaging.

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References: (1) Abdel-Aty H, JACC 53:1194, 2009. (2)Tilak GS, Invest Radiol 43:7, 2008. (3) Giri S, JCMR 11:56, 2009. (4) Kim D Magn Reson Med 62:300, 2009. (5) Huang C, ISMRM 2011:2763. (6) Huang C, MRM, in press. (7) Altbach MI, MRM 54:549, 2005.