Indirect Echo Corrected Fast T2 mapping of the Heart from Highly Undersampled Radial FSE Data Using the CURLIE Reconstruction

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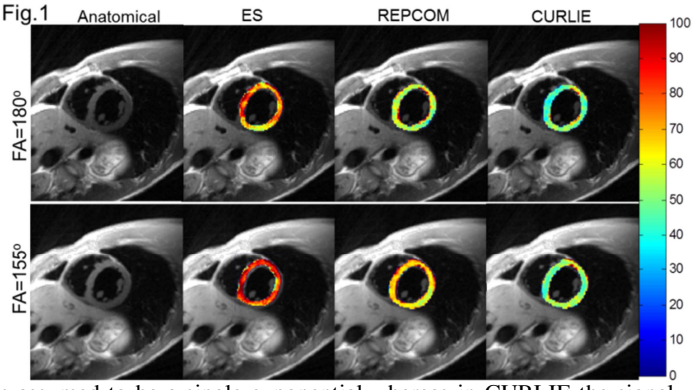
Introduction: T2-weighted imaging is an important modality in cardiac MR and is used for the diagnosis of a series of pathologies. As an alternative to T2-weighted imaging, T2 mapping of the heart has recently been proposed [1,2]. Fast T2 mapping can be achieved using a fast spin echo pulse sequence (FSE). The advantages of FSE sequences for T2 mapping are that many TE time points (ie, time points = ETL) are collected within a TR period which speeds up data acquisition without compromising spatial resolution. Furthermore, misregistration between TE data sets is minimized. A drawback of using an FSE acquisition is that indirect echoes (eg. stimulated echoes) affect T2 estimation. Indirect echoes are a consequence of imperfections in the refocusing pulses and artificially increase T2 values. The effect of indirect echoes is more pronounced for longer T2s and when the flip angle of the refocusing pulses (FA) deviates from the ideal 180°. Also, indirect echoes render T2 values dependant on the echo train length.

Our group has developed a double-inversion radial FSE (DIR-RADFSE) technique [3] for obtaining T2 maps of the heart using highly undersampled radial data, thus allowing T2 mapping from data acquired with high spatial and temporal resolution in a breath hold. Very recently we incorporated the effects of indirect echoes in the reconstruction technique to eliminate the bias in T2 estimates due to imperfect refocusing pulses and B1 inhomogeneity. The new reconstruction algorithm is called *CUrve Reconstruction via pca-based Linearization with Indirect Echo compensation* (CURLIE) [4,5]. In this work we evaluate the advantages of CURLIE and compare the method to two previous reconstruction algorithms: echo sharing technique (ES) [6], and REPCOM, a model-based reconstruction similar to CURLIE but which does not correct for indirect echoes [7].

Methods: To evaluate the effects of imaging conditions on the reconstruction of T2 maps, several experiments were conducted on 7 healthy subjects In these experiments we varied the FA (FA=180° and 155°) and the receiver bandwidth (rBW=± 31.25 kHz and ± 62.5 kHz) such that the acquisition time through the echo train changed (from 144 ms to 112 ms) with the shorter acquisition for higher rBW and shorter FAs. Data were acquired at 1.5T (GE Signa NV-CV/I scanner) with DIR-RADFSE with a total of 256 x256 and ETL=16 to yield 16 highly undersampled TE data sets (16 radial lines per TE). Other parameters were: TR = 1RR, NEX=1, slice thickness 8 mm, FOV=48 cm. Data for each subject were acquired twice for each experiment in the same midventricular short axis view.

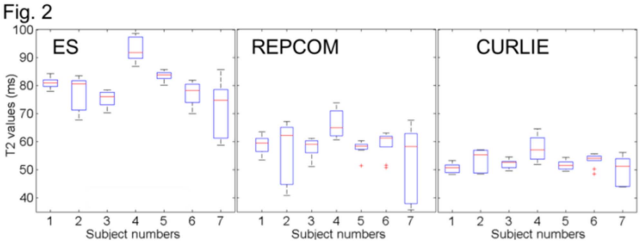
Fig.1



Data were reconstructed using ES and the model-based algorithms: REPCOM and CURLIE. ES uses data at a specific TE in the central part of k-space and the data at other TEs in the outer part of k-space. The mixed k-space data sets are used to generate TE images with a contrast similar to the data in the central part of k-space; a T2 map is generated from the TE images [6]. In the model-based reconstructions the TE sets are not mixed but used in an iterative manner where the expected T2 decay signal model is fitted to the acquired TE data [4,5,7]. In both REPCOM and CURLIE the T2 signal decay model is linearized using principal component decomposition. Penalty terms are enforced to exploit the spatial and temporal sparsity of the TE images according to the compressed sensing theory. The main difference between the two algorithms is that in REPCOM, the T2 decay signal model is assumed to be a single exponential whereas in CURLIE the signal model incorporates the effects of indirect echoes. Since the latter is a highly non-linear signal model, the linearization step in the model-based reconstruction is of critical importance. The number of principal components for the linearization of the signal model was 3 for REPCOM and 6 for CURLIE. A weight of 0.01 was used for the penalty terms.

Once T2 maps were generated with the 3 reconstruction methods for each subject and experiment, mean T2 estimates within manually drawn ROI on the LV myocardium were used for comparisons.

Fig. 2



Results: Examples of anatomical images and T2 maps (overlaid on the anatomical image) reconstructed with the ES, REPCOM and CURLIE algorithms are shown in Fig. 1. The data corresponds to two experiments where the difference between acquisition parameters was the FA of the refocusing pulse. The choice of FA=155° is based on the fact that this FA is commonly used in double inversion FSE methods to minimize the effects of motion during data acquisition. Note that the ES reconstruction yields significantly higher T2 values compared to REPCOM; REPCOM values are slightly higher compared to CURLIE. The increase in T2 values is a consequence of the lack of compensation for indirect echoes in ES and REPCOM. Moreover, note that when the FA is decreased from 180° to 155°, T2 values increase further for ES and REPCOM. CURLIE is not affected by the change in FA because indirect echoes are taken into account.

Figure 2 shows the effect of imaging parameters for each subject in the study (shown as 1-7). In the figure each boxplot represents the median of T2 estimates, 25-75th percentiles, and the minimum and the maximum for a set of 5 experiments where the rBW and/or FA were varied. For all subjects T2 values with ES are higher than with REPCOM and CURLIE (as in Fig. 1). Across all subjects CURLIE showed less variability in T2 estimation when imaging conditions are changed. The mean T2 variance (ms^2) across all experiments and all subjects was 27.56, 52.65, and 10.56 for ES, REPCOM, and CURLIE, respectively.

Conclusions: In this work, we present results of T2 mapping using undersampled DIR-RADFSE data and evaluated T2 estimation for 3 reconstruction algorithms. Results showed that CURLIE yields T2 estimates that are less dependent on the experimental conditions because the effects of indirect echoes are accounted for. These improvements should make T2 mapping more reliable and practical for clinical use.

Acknowledgement: NIH grant R01HL085385 and the Edward and Virginia Madden Award. **References:** (1) Giri S, et al., JCMR 11:56, 2009. (2) Kim, D., et al.,MRM, 62:300, 2009. (3) Altbach., et al., JCMR, 2012 14(suppl 1). (4) Huang C., et al., ISMRM, 20:362, 2012. (5) Huang., et al., MRM, 2012, in press. (6) Altbach., et al., MRM 54:549, 2005. (7) Huang C., et al., MRM, 67:5, 2012.