An Indirect Echo Compensated Reconstruction Algorithm for T2 Mapping of The Liver from Highly Undersampled Radial FSE Data

Chuan Huang[1,2], Abhishek Pandey[3], Tomoe Barr[4], Ali Bilgin[3,4], and Maria I Altbach[1]

[1]*Department of Medical Imaging, University of Arizona, Tucson, AZ, United States,* [2]*Center for Advanced Radiological Sciences, Department of Radiology, Massachusetts General Hospital, Boston, MA, United States,* [3]*Electrical and Computer Engineering, University of Arizona, Tucson, AZ, United States,* [4]*Biomedical Engineering, University of Arizona, Tucson, AZ, United States*

Introduction: Early detection and classification of hepatic tumors and chronic liver disease are two important clinical problems. T2 mapping has been used for the characterization of these pathologies but its application in the clinic has been limited by the long acquisition time of spin echo based T2 mapping techniques and the lack of spatial-temporal resolution and misregistration of data when fast single-shot based techniques are used.

A radial Fast Spin Echo (radFSE) sequence has been previously proposed for fast T2 mapping [1]. In radFSE, data for several TE time points (16 or more) are collected within a TR period which speeds up data acquisition while maintaining spatial resolution. Furthermore, misregistration between TE data sets is minimized due to the nature of the acquisition. When radFSE is combined with an undersampled acquisition scheme, T2 mapping can be achieved in a single breath hold. Thus, the reconstruction of T2 maps from undersampled radFSE data has been the subject of recent investigation and several algorithms (based on echo sharing techniques or model-based reconstruction) have been proposed [2, 3]. However, most of the reconstruction methods do not take into account the effects of indirect echoes (such as stimulated echoes) in the signal model leading to T2 values that are dependent on the refocusing pulse slice profile and/or B1 inhomogeneities. Recently, we proposed a reconstruction algorithm – CURLIE [4, 5] (*CUrve Reconstruction via pca-based Linearization with Indirect Echo compensation*) – which combines a principal component model-based algorithm with a slice-resolved extended phase graph (SEPG) [6] signal model thus incorporates the effect of indirect echoes. In this abstract, we demonstrate the ability to obtain accurate T2 maps from liver with radFSE data acquired in a single breath hold without the T2 bias induced by indirect echoes.

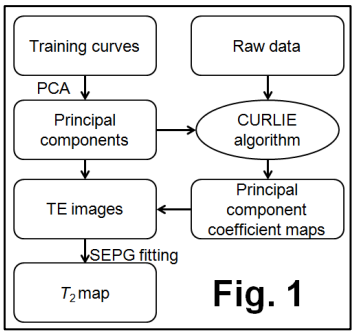


Fig. 1

Methods: A flowchart of the CURLIE algorithm is shown in Figure 1. The training curves generated by SEPG signal model are used to obtain principal components (PCs). The PCs are used in CURLIE to obtain PC coefficient maps from which the TE images are calculated and a T2 map with indirect echo effect corrected is derived using SEPG fitting [4-6].

	Vial	Gold standard	RFA=180°	160°	140°	120°
REPCOM	A	210.0	215.7	219.7	225.4	244.2
	B	159.3	165.1	167.7	168.7	181.9
	C	80.7	83.0	83.9	84.3	90.8
CURLIE	A	210.0	208.1	205.5	202.6	201.6
	B	159.3	159.7	157.8	152.9	151.8
	C	80.7	81.1	80.4	77.0	76.8

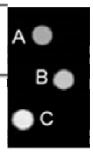
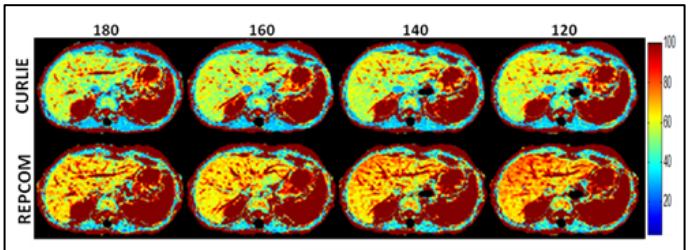


Fig. 2

A phantom made up of vials filled with $MnCl_2$ solutions to yield different T2s was prepared. Phantom and in vivo data sets were acquired at 1.5T (GE Signa NV-CV/i) using radFSE. Phantom data were acquired using the body coil: echo spacing = 12.11ms, ETL = 16, TR = 1 s, slice thickness = 8mm, receiver bandwidth (RBW) = ±15.63 kHz. An acquisition matrix of 256(frequency)×256(phase) was used, resulting in 16 k-space lines per TE. In vivo data from volunteers were acquired in a breath hold with an 8 channel torso coil: echo spacing = 8.93 ms, TR = 1.5 s, RBW = ±31.25 kHz; slice thickness = 8 mm, ETL=16 and acquisition matrix = 256x256. The refocusing flip angle (RFA) of the refocusing pulses was changed (to induce various degrees of pulse imperfections) by controlling the power of the played RF pulse in the sequence.

The decay curves were first reconstructed by CURLIE and T2 estimates were obtained by SEPG fitting on the curves. Single exponential fitting without indirect echo compensation, using images reconstructed by a single-exponential model-based T2 mapping technique (REPCOM [3]), was also performed for comparison.

For the quantitative comparison of the T2 of the liver parenchyma, an automatic segmentation technique [7] was used to segment out the vessels within the liver.



Mean T2 values of liver tissue

	180°	160°	140°	120°
CURLIE	56.8	55.9	57.2	58.0
REPCOM	66.5	66.7	70.9	72.4

Fig. 3

Results: Figure 2 shows the phantom results. The gold standard T2 was obtain by a separate single-echo spin-echo acquisition (hence no indirect echo effect). Note that T2 estimates without compensation for indirect echoes (REPCOM) deviate from the gold standard as the RFA deviates from 180°; the error can be larger than 16%. However, the T2 values estimated by CURLIE with SEPG fitting are less dependent on the RFA, and the errors are all below 5%.

Figure 3 shows the T2 maps and the quantitative results from in vivo data acquired with different RFAs. The T2 means were calculated from a liver mask where vessels were removed (an example of the mask is shown). Similar to phantom results, the T2 maps and corresponding T2 means obtained by CURLIE with SEPG fitting are independent of the RFA. On the other hand, when indirect echoes are not taken into account as in REPCOM there is a clear increase of T2 values in the liver. The T2 bias increases as the RFA deviates from the ideal 180°. For clarity the T2 values in Figure 3 are capped to 100 ms, but a similar trend is seen for the T2 values of organs with higher T2 (eg, kidney and spleen)

Conclusions: In this work, we demonstrated that the CURLIE-SEPG algorithm yields indirect echo compensated T2 maps from highly undersampled radFSE data acquired in a single breath hold. The data used in the reconstruction has high temporal and spatial resolution. We showed that the technique is independent on the RFA and thus immune to B1 inhomogeneities and B1 mis-calibration. Furthermore, the capability of obtaining T2 maps with RFA significant lower than 180° is particularly important for T2 mapping at high fields where the use of 180° RFA is limited by the power deposition constraint.

Acknowledgement: NIH grant: HL085385

References: 1.Altbach MI *et al* MRM 54 pp549 2.Block KT *et al* IEEE TMI, 2009 (28). pp1759 3.Huang C *et al*. MRM 67(5) pp1355 4.Huang C *et al* MRM, in print 5.Huang C *et al* ISMRM 2012: p362 6.Lebel RM, Wilman AH, MRM 64 (4) pp1005 7.Bilgin A *et al* ISMRM 2011: p2945