Robustness of R2* mapping for liver iron assessment at 1.5T and 3T

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Target audience: Basic researchers working on MRI relaxometry, and clinical scientists working on iron quantification.

Purpose: Techniques are needed for rapid, accurate and robust assessment of liver iron overload. R2*-MRI has the potential to provide rapid and accurate iron quantification (1,2). However, the robustness of liver R2* mapping to variations in imaging parameters (particularly spatial resolution and echo time combination) is unknown. Indeed, lack of robustness is the largest criticism of R2* mapping, limiting its widespread acceptance for iron quantification. The purpose of this study was to evaluate the robustness of R2* mapping in subjects with liver iron overload using fat-corrected chemical shift encoded multi-echo acquisitions with varying image orientation, spatial resolution and echo time combinations, at 1.5T and 3T.

Methods: In accordance with the local IRB, 24 subjects (9 controls and 15 subjects with liver iron overload, 13 men/11 women, age range 12-70 years) were scanned at both 1.5T (HDxt, GE Healthcare, Waukesha, WI) and 3T (GE MR750). At each field strength, imaging was performed using a multi-echo chemical shift encoded 3D-SPGR acquisition for fat-corrected R2* mapping (3). Using this acquisition four different acquisitions were performed (Table 1). Three reconstructions of the same source data were performed for each protocol. All data were reconstructed with simultaneous fat-water-R2* estimation so R2* maps were corrected for the presence of fat. The three reconstructions included: 1) complex-fitting (4), 2) magnitude-fitting (4), 3) complex-fitting including correction for background B_0 field variations (5).

Table 1: *Protocols*

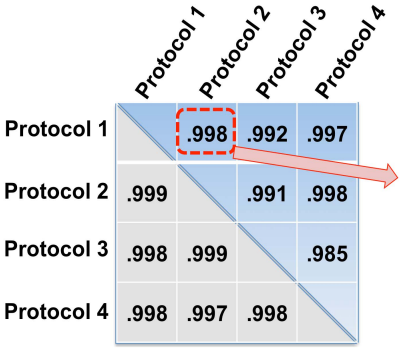
		1.5T		3T	
Protocol	**Orientation**	**#TEs**	**TE_{init}/ΔTE/TR**	**#TEs**	**TE_{init}/ΔTE/TR**
1	Axial 8mm	6	1.2/2.0/14.1	6	1.2/1.0/8.6
2	Axial 6mm	6	1.2/2.0/14.1	6	1.2/1.0/8.6
3	Coronal 5mm	6	1.2/2.0/13.4	6	1.2/1.0/8.6
4	Axial 8mm	12	0.9/0.7/11.0	8	0.6/0.6/5.9

Measurements were made using regions of interest drawn and co-localized in each of the 9 Couinaud segments. Average R2* (and standard deviation) were measured for 1) each of the three reconstructions, 2) for each of the four protocols and 3) for both field strengths, for a total of 9 x 3 x 4 x 2 = 216 measurements per patient. Whole-liver R2* measurements were obtained by weighted averaging of segment measurements. Data were analyzed for each of the three reconstructions by linear regression of R2* measured with each pair of protocols at each field strength.

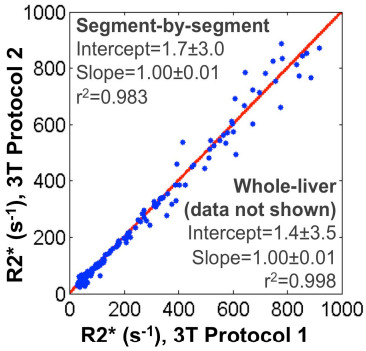
Results: Data from one subject was discarded due to severe motion artifacts. Figure 1 shows regression results for complex fitting R2* measured with each pair of protocols. Whole liver R2* correlations had r^2>0.98, whereas segment-by-segment R2* correlations had r^2>0.95 for every pair of protocols. Regression slopes were between 0.96-1.04 for every pair of protocols, except Protocol 3 (Coronal 5mm slices) at 3T, where slopes relative to the other three protocols were between 0.87-0.90. This was likely due to the noticeably lower SNR due to thin slices and relatively long TEs (TE_{init}=1.2ms) in this protocol, producing negative bias at very high R2*. Excluding subjects with mean R2*>600, the slope of R2* at 3T (Protocol 3) with respect to protocols 1, 2, and 4 was 0.99±0.02, 1.00±0.02 and 1.01±0.02, respectively.

Correction for background B_0 variations produced similar results as "standard" complex-fitting. For magnitude fitting R2* measurements, correlations between protocols (whole-liver: r^2>0.95) are lower than for complex-fitting, due to noise floor effects. Slopes are also further from 1.0, particularly for Protocol 3 at 3T compared to the other 3T protocols (0.71-0.85 including all subjects; 0.90-0.93 excluding subjects with R2*>600).

Fig 1: *Complex-fitting: comparison between pairs of protocols at 1.5T and 3T.*



(a) Whole-liver R2*: r^2 between each pair of protocols
Blue = 3.0T comparison
Gray = 1.5T comparison



(b) Example regression between protocols 1 and 2 at 3.0T, performed over all 9 liver segments as well as whole-liver measurements.

Discussion: These results show excellent robustness of fat-corrected liver R2* mapping in subjects with iron overload, ie: R2* measurements are very similar over all liver segments for multiple acquisitions with different spatial resolutions and TE combinations. Further, complex fitting is needed in order to avoid noise floor effects, particularly in cases of high R2*. Correction for background B_0 variations has minimal influence with the protocols used in this work (slice thickness ≤ 8mm). At very high R2* values, it is necessary to acquire data with short echoes and high SNR in order to minimize errors even with complex fitting.

Conclusion: Liver R2* mapping can be performed with excellent robustness to varying imaging parameters, and constitutes a promising approach for rapid, accurate and robust liver iron quantification at both 1.5T and 3T.

References: (1) Wood et al, Blood 2005;106(4):1460-1465. (2) Hankins et al, Blood 2009;113(20):4853-4855. (3) Meisamy et al, Radiology 2011;258(3):767-775. (4) Hernando et al, Magn Reson Med 2010;64(3):811-822. (5) Hernando et al, Magn Reson Med, 2012;68(3):830-840.

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