Liver R_2^* Dependence on Liver Storage Iron in Highly Iron Overloaded Patients: comparing 1.5 T to 3 T

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Target Audience. Clinicians and scientists interested in MRI based liver iron content (LIC) determination.

Purpose. To study liver R_2^* in iron overloaded patients at 3T as a function of Liver Iron Content (LIC) with respect to theory.

Theory. R_2^* of liver is expected to depend linearly on LIC. The slope is iron relaxivity, the abscissa the R_2^* value of iron-free tissue.

Methods. 71 patients highly transfused patients with liver iron overload were enrolled in the study approved by our local ethics committee. After giving informed written consent, 36 patients (age 8 … 75 years, mean age 27 y) were scanned at 1.5 T (Siemens Avanto), 48 patients (age 8 … 72 years, mean age 28 y) were examined at 3T (Siemens Skyra). This means that 13 patients were scanned at both scanners. Breathhold multicontrast RF spoiled GRE sequences with 12 echoes each were performed. For parameters see Tab. 1.

	min. TE	echo-spacing	TR [ms]	flip angle (FA)
1.5 T	1.19 ms	1.19 ms	120	20°-30°-50°-90°
1.5 T	1.59 ms	1.59 ms	126	20°-30°-50°-90°
3T	0.9 ms	0.8 ms	250	20°-30°-50°-90°
3T	1.3 ms	0.8	260	20°-30°-50°-90°

Tab. 1. MRI GRE protocols for 1.5 and 3 T.

Note that all protocols were acquired with four flip angles (FA), requiring a total of 8 breathholds in each scanner. R_2^* values in three manually drawn regions of the liver were calculated by Levenberg-Marquardt fit of the signal to theory incorporating signal dependence on liver fat fraction (Lff) as well as liver R_1. Noise was also included as free parameter, the others were S_0 (theoretical signal at TE=0) and R_2^*. The fit procedure was tested for reliability with simulations.

For all 71 patients, five single-echo spin echo sequences with different TE were acquired at 1.5 T for commercial analysis (Ferriscan®, cf. [1]). Results are referred to as LIC in the following. Patients exceeding the upper limit for this method (769 mmol Fe/kg liver dry tissue) were excluded.

R_2^* dependence on LIC was determined by evaluating R² for linear correlation between R_2^* and LIC. Also, corresponding p values were evaluated.

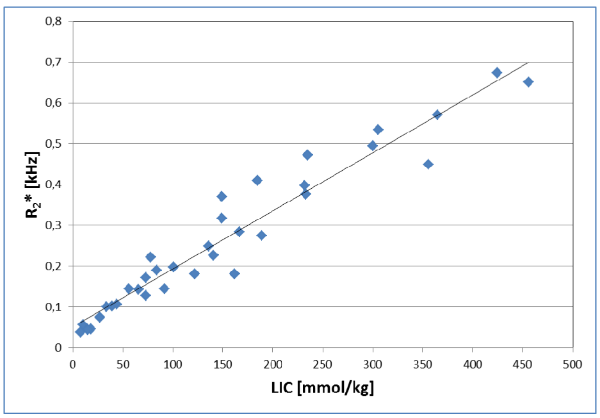

Fig. 1. R2* versus liver iron content for 1.5 T. The solid line is the regression line.

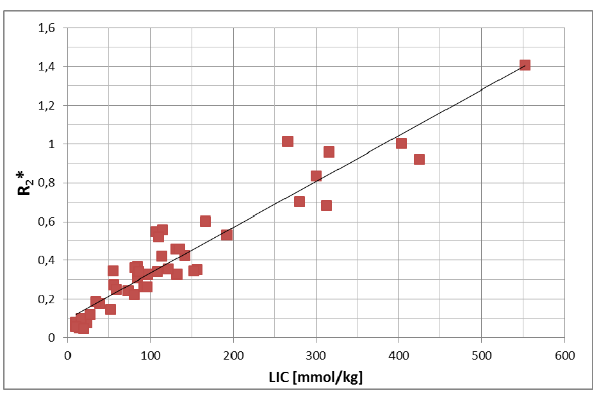

Fig. 2. R2* in kHz versus liver iron content for 3 T. The solid line is the regression line.

Results. Two patients exceeded the limit for LIC determination and were excluded. As expected from theory, R_2^* showed a linear dependence on LIC (Fig. 1,2) for both field strengths at a significance level $p<0.001$. For details cf. Tab. 2. R_1 was independent of LIC for both field strengths (last column of Tab. 2).

	R²	slope	absc.	R_1 [Hz]
1.5 T	0.93	1.42 Hz*kg/mmol	51 Hz	5.2 ± 1.
3 T	0.9	2.37 Hz*kg/mmol	98 Hz	4.3 ± 0.4

Tab. 2. Results of linear regressions R_2^* vs. LIC.

Discussion.. We were able to implement a fit procedure with the capability of reliably determining R_2^* values above 1 kHz resulting in T_2^* values below 1 ms with standard multicontrast GRE sequences at various flip angles for use in clinical routine. The problem with these short T_2^* observed in high iron overloaded patients is that at TE for the first in-phase condition (2.5 ms at 3T) liver signal is barely above MR signal noise. Therefore, shorter TEs have to be included which require liver fat fraction as additional fit parameter. At 3 T, we were able to measure only two TE shorter than the first in-phase TE in one echo train. This would lead to an underdetermined problem with only three measurement points for determination of four unknowns (S_0, R_2^*, Lff and noise). By including multiple flip angles, signal dependence on R_1 had to be considered as the fifth fit parameter, but thereby we got 12 measurement points which allowed definite determination of parameters.

In spite of superior SNR at 3T, 1.5 T performs better, probably by reason of longer T_2^*. Due to shorter TE for in-phase echo at 3 T, readout had to be shortened by elevating receiver bandwidth, increasing image noise.

Conclusion. Using GRE protocols with different flip angles, narrow echo spacing and a sophisticated fit procedure, we were able to demonstrate R_2^* dependence on LIC at 1.5 and 3 T as expected by theory with standard GRE sequences. At both field strengths, we see a good chance of determining LIC from multicontrast GRE acquisitions at various flip angles.

References. 1. T. G. St. Pierre et al.: Noninvasive measurement and imaging of liver iron concentrations using magnetic resonance. Blood 2005; 105 (2): 855-61