Liver Iron Measurement and Mapping using MRI

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MRI can be used for the non-invasive measurement of liver iron concentration (LIC) in conditions of body iron overload via quantitative image measurement of the hydrogen proton transverse relaxation rate (R_2) [*Clark PR & St. Pierre TG. Magn. Reson. Imaging, 18 (2000) 431-438* ; *Clark PR, Chua-anusorn W & St. Pierre TG. Magn. Reson. Med., 49 (2003) 572-575*]. The possible range of LIC measurement is further extended by a bi-exponential R_2 imaging technique [*Clark PR, Chua-anusorn W & St. Pierre TG. Magn. Reson. Imaging, 21 (2003) 519-530*].

The accuracy and reproducibility of R_2 imaging on aqueous $MnCl_2$ phantoms with a range of R_2 values covering those encountered in human liver has been demonstrated on five 1.5 T whole body imaging units. The mean relaxivity value for the five scanners was 74.1 s^{-1} $(mM)^{-1}$, with a SD of 0.3 s^{-1} $(mM)^{-1}$. The coefficient of variation between the five scanners was less than 0.5%.

To demonstrate the reproducibility of R_2 imaging on the liver *in vivo*, 10 volunteers (3 healthy, 2 with hemochromatosis, and 5 with β-thalassemia) were measured twice each on 2 different scanners a day apart. The precision of inter-scanner R_2 image measurement of the liver was 7.7%, with a non-significant systematic difference between scanners of 1.2%.

For liver iron calibration curve development, 105 volunteers (32 with hepatitis, 23 with hemochromatosis, and 50 with β-thalassemia) who were undergoing liver biopsy during the course of their treatment were measured. The mean R_2 in the right-hand side of the liver for slices of maximal cross-section was found to correlate significantly with needle liver biopsy LIC (rho = 0.98). A universal calibration curve was applicable to all patient groups, and covered the entire range of LICs presented, from 0.3 to 43 mg of iron per gram dry tissue (Figure 1). The accuracy of the calibration over different ranges of LIC was estimated by calculating the SD of the LIC differences between the calibration and the ranked order data, yielding the following uncertainties and (ranges): ± 0.1 (0.3 - 1.8); ± 0.3 (1.8 - 5.0); ± 0.9 (5 - 20); and ± 1.1 (20 - 43) mg Fe/ g dry tissue.

The results of this study demonstrate that R_2 image measurement (as shown for 3 subjects in Figure 2) can be used in a machine independent manner for the non-invasive measurement of LIC, from normal to highly loaded liver iron levels (approx 40 mg Fe/ g dry tissue).

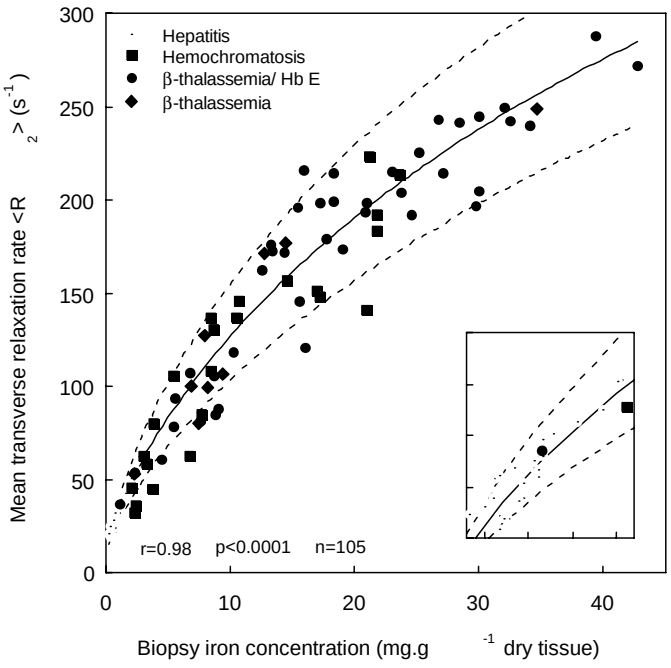

Figure 1. Liver <R_2> measurement in 105 volunteers for the right hand side of the liver versus needle biopsy iron concentration. (The scatter is due to the sampling variability of needle biopsy.) The solid line is the calibration curve with a Pearson's correlation coefficient of 0.98. The dashed lines illustrate ± 40% intervals about the needle biopsy measurement that correspond to the approximate uncertainty on a single biopsy measurement in end stage liver disease.

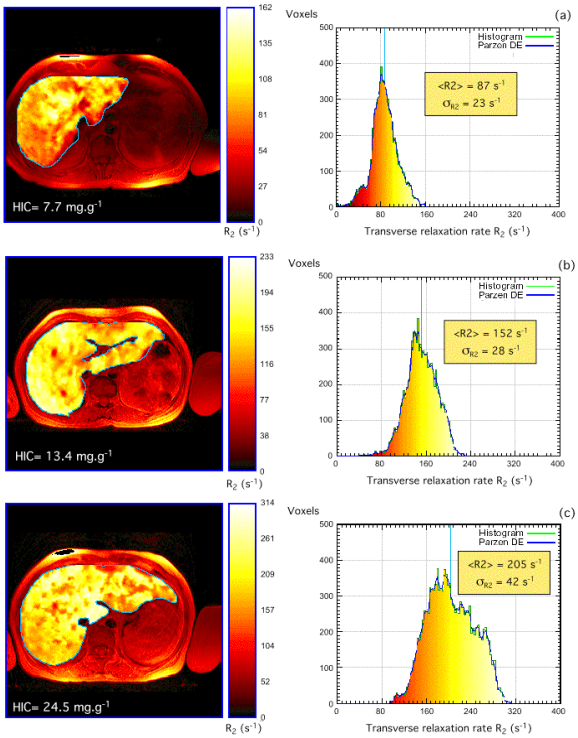

Figure 2. Hepatic R_2 images (superimposed on 6ms spin-echo images) and R_2 distributions for 3 subjects with increasing levels of iron overload and different pathological conditions (a) Hemochromatosis (b) β-thalassemia (c) β-thalassemia/ Hb E. The HIC label on the images is the liver iron concentration measurement from needle biopsy assay.