Quantification of Liver Iron with Rapid 3D R1 and R2 Mapping with DESPOT1 and DESPOT2

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Introduction:

Hemochromatosis is an inherited disorder characterized by excessive storage of iron with the liver, heart, pancreas and other abdominal organs. With early diagnosis and treatment, organ damage can be minimized. Presently, the gold standard method for liver iron quantification is liver biopsy, an invasive and painful procedure. Alternative diagnosis methods, such as blood serum iron and ferritin levels[1] and transferrin saturation[2] indicate abnormal iron levels, but have poor specificity and sensitivity. Prior studies[3-5] have investigated the use of MRI as a non-invasive liver iron quantification technique and have shown good correlation between R2 (1/T2) as well as T1-weighted signal intensity and liver iron content (HIC). Unfortunately, the methods described in these studies have not been widely adopted clinically due to their long acquisition and post-processing times, limited resolution, restriction to 2D imaging and their inability to detect mild iron overload. In this study, we evaluated the 3D DESPOT1 and DESPOT2 relaxometry methods[6] as a means of non-invasive liver iron quantification. The methods offer rapid acquisition and processing speed, provide 3D coverage of the whole liver and the collection of both T1 and T2 data may provide more accurate evaluations of liver iron, particularly at very low and high iron concentrations

Methods:

3D abdominal R1 (1/T1) and R2 (1/T2) maps (40cm x 30cm x 36cm field of view with a 200 x 150 x 60 matrix) of 4 hemochromatosis patients and 1 normal control were acquired using the DESPOT1 and DESPOT2 relaxometry methods with the following parameters: DESPOT1: TR/TE=3.5/1.9, flip angles= 3,6,9,12,15,18,21,24 degrees, DESPOT2: TR/TE=3.5/1.7, flip angles=8,16,24,32,40,48,56,64 degrees. Imaging time for each volume data collection (i.e. each flip angle) was 14s, allowing data acquisition to be performed during breath-hold. The reproducibility of both methods was determined by acquiring three sets of DESPOT1/DESPOT2 data of the same normal volunteer on separate occasions. Reproducibility was calculated as the average percent standard deviation of repeated measurements.

Average R1 and R2 values for the liver, spleen, kidney, muscle and fat were calculated from regions of interest placed throughout each tissue. Liver R1 and R2 values were compared with gold standard liver iron concentration, HIC (determined by biopsy) to determine the experimental correlation. As biopsy was not performed on the control volunteer, a normal HIC value (~30 μmol/g) was assumed.

Results:

Matched R1 and R2 maps of a mildly diseased hemochromatosis patient are shown in Fig. 1 a and b. The images show good signal-to-noise and reveal the importance of large volume coverage. The high vascularization of the liver makes it difficult to select large homogeneous regions or interest, making the acquisition of multiple slices an advantage when calculating average R1 and R2 values. Plots of R1 and R2 vs. HIC (Fig. 1 c and d) reveal high correlation between R1 and R2 and HIC with r^2 values of 0.9874 and 0.9245, respectively. Reproducibility of the R1 and R2 measurements was found to be good, with 0.19s^{-1} for R1 and 25 s^{-1} for R2. This is shown visually in Fig. 1 e. No significant differences were found between the means at the .05 level.

Finally, a plot of average R1 vs. R2 of all investigated tissues for all individuals is shown in Fig. 1 f. As expected, R1 and R2 values for fat, muscle and kidney form tight clusters among all individuals. Spleen and liver, however, show increases in R1 and R2 with increased HIC, causing a spreading along a linear axis in the 2-dimensional feature space with an R2/R1slope ratio of 52.4. It is clearly evident that R2 is far more sensitive to changes in HIC than R1, but has 13 times greater variability. Taking both sensitivity and variability into account, R2 appears to be a better choice for monitoring absolute HIC change.

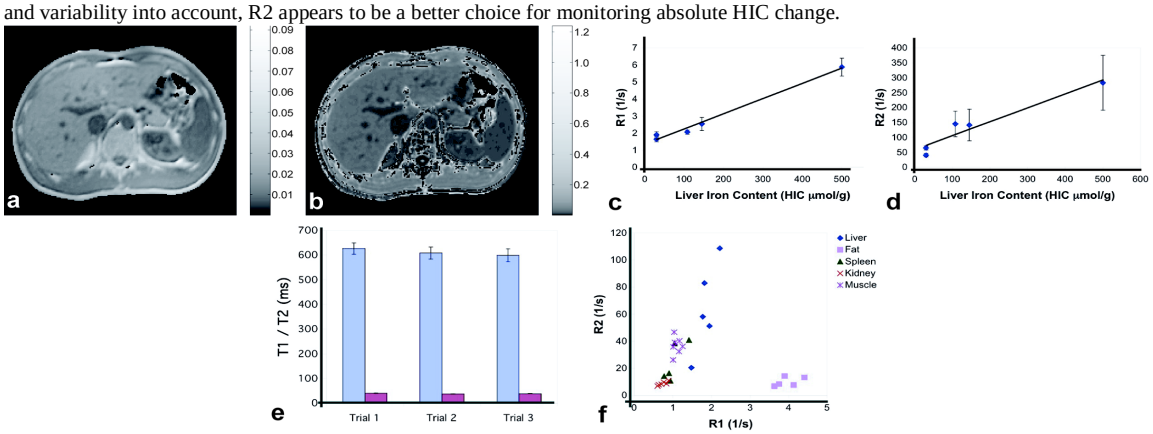

Figure 1: Matched liver R1 (a) and R2 (b) maps. Plots of R1 vs. HIC (c) and R2 vs. HIC (d). Reproducibility of T1 and T2 from 3 separate acquisitions on a normal volunteer (e) and R1 vs. R2 for all tissues examined for all individuals (f).

Discussion/Conclusions:

Previous investigations of R1 and R2 in hemochromatosis have been hindered by lengthy acquisition times, low-resolution 2D single-slice imaging and have been limited to either R1 or R2. Here we have demonstrated the clinical feasibility of the DESPOT1 and DESPOT2 relaxometry methods as a non-invasive, high speed, high-resolution, 3D method of liver iron quantification. Both R1 and R2 show high correlation with HIC with good reproducibility. R2 has greater sensitivity to absolute changes in HIC (52x that of R1) and despite having greater variability appears to be the parameter of choice in monitoring and measuring HIC.

References:

[1] Lipschitz et al. New England J. of Med. 1974;290:1213-1216. [2] Edwards et al. New England J. of Med. 1977;297:7-13. [3] Start et al. Radiol. 1985;154:137-142. [4] Israel et al. MRM 1989;7:629-634. [5] Bonkovsky et al. Radiol. 1999;212:227-234. [6] Deoni et al. MRM, 2003;49:515-526.