Relationship between Liver R1, R2, and R2* at 1.5T

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Target Audience Clinicians and engineers interested in imaging and quantifying tissue iron load at 1.5 Tesla.

Purpose The use of MRI in the quantification of tissue iron is considered an essential component of clinical management. Currently, R2 and R2* imaging have been calibrated to quantify liver iron concentration (LIC) at 1.5T. The relationship between liver R1 and LIC has been estimated in vitro [1], and in animals [2,3] but never studied in-vivo. We proposed that liver R2 and R2* LIC estimates can be used to develop a calibration between R1 and LIC in humans.

Methods All patients underwent abdominal MRI scans at 1.5T as part of routine clinical surveillance. Scan were acquired on a 1.5T Philips (Achieva, 8-element torso coil, System 3.2.2). Liver R1 were measured using a Look-Locker sequence, field of view 30-40 cm, 48 X 64 matrix, slice thickness 10 mm, echo time 0.95 ms, bandwidth 4883 Hz/pixel, 7 degree flip angle, and 52 inversion times from 153-953 ms. Liver R2* was measured using a multiple echo gradient sequence with the following parameters: 3 slices, field of view 30-40 cm, 84 x 84 matrix, slice thickness 10 mm, repetition times 50 ms, bandwidth 3840 Hz/pixel, and 16 echoes equally spaced between 0.98 and 12 ms. Liver R2 was measured using a single spin echo protocol with paired 90 spin-echoes collected one TE per breath-hold. Imaging parameters were 4 slices, field of view 30-40 cm, matrix size of 64 x 64, slice thickness 10 mm, repetition time 300 ms, bandwidth 1310 Hz/pixel and echo times of 3.9, 4.2, 4.5, 5, 8, 12, 18, and 30 ms. A total of 62 patients participated in the study (26 male 36 female with an average age of 18.3 ± 14 years, with females ranging of age 5 days to 66 years and males ranging from 5 years to 32 years). Patients had Thalassemia disorders (n=21), Sickle Cell Anemia (n=20) and other rare anemias (n=21).

Results As seen in Figure 1, liver R1 was linearly correlated with liver R2 ($r^2 = 0.66$, $p<0.0001$); linear fit was superior to power law, logarithmic, or polynomial fit. In contrast, liver R1 exhibited a curvilinear relationship with liver R2* ($r^2 = 0.68$, $p<0.0001$). Power-law and logarithmic fitting were equally efficacious. LIC by R2 and by R2* were highly concordant, with an r^2 of 0.97 ($p<0.0001$).

Discussion We believe that liver R1 is sensitive enough to quantify liver iron concentration, albeit with more LIC uncertainty than with R2 or R2* measurements. Liver R1 and liver iron have a nonlinear relationship resembling R2-iron calibration curves. The source of R2 curvilinearity results from static refocusing caused by secondary iron "structure" within hepatocytes [4]. However, the mechanisms responsible for nonlinear R1 relaxation with iron requires further study. Our observed in-vivo relaxation rates were higher than previously observed in liber biopsy specimens studied at 60 Mhz [1]. However, R1 values measured in cutting needle biopsy samples were likely biased because of tissue disruption. While the Ghugre data did not suggest a nonlinear relationship between R1 and iron, the sample size was too small to identify one. Studies in the iron dextran gerbil model suggest a linear R1-iron relationship in nonchelated animals [2] but nonlinear behavior after chronic chelation therapy [3].

Conclusion These results suggest that liver R1 estimates can complement R2 and R2* assessments of LIC; the relatively high scatter between liver R1 estimates and predicted LIC may preclude its use as a sole metric. However, with a minimum echo time under 1 ms, it is capable of providing LIC information over a much larger dynamic range than either R2 or R2*. We believe that R1 may also contain other information regarding liver health, such as inflammation and fibrosis, however further work is necessary to characterize these relationships.

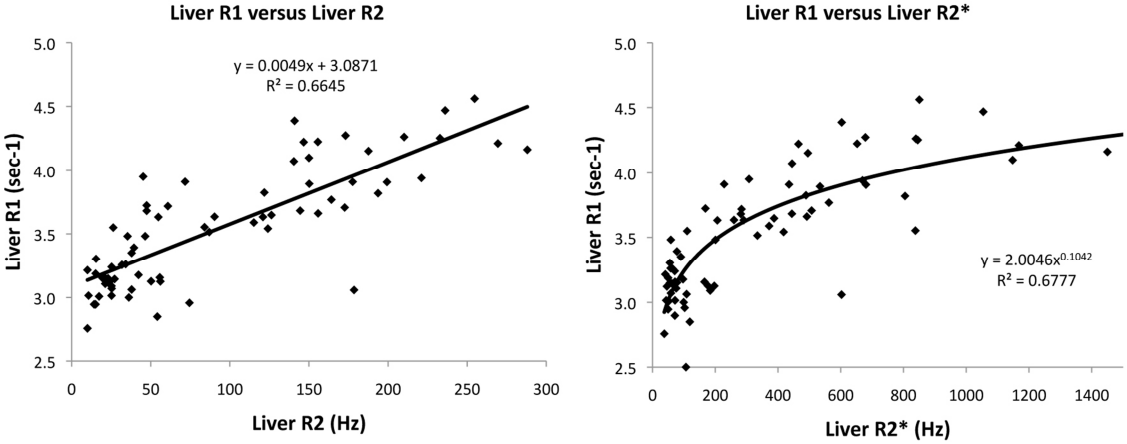

Figure 1 - Comparison of liver R1 and R2 (left) demonstrates a linear correlation. Liver R1 and R2* (right) show a curvilinear relationship.

References

[1] Ghugre et al, Mag Res Med, 54(5):1185-93, 2005 [2] Wood et al, Circulation 112(4):535-43, 2005; [3] Wood et al, Mag Res Med, 60(1):82-89, 2008 [4] Ghugre et al, MRM, 65(3):837-47, 2011