# MRI Measurements of Magnetic Susceptibility of the Liver in Normal Subjects

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**Introduction**:

Accurate assessment of the body iron is essential for managing iron-chelation therapy in iron overload patients to prevent iron toxicity while avoiding the adverse effects of excess chelator administration. While SQUID can measure iron overload [1], it is not widely accessible for patients, and to date, there is no other reliable and non-invasive technique for the liver iron measurement. Current magnetic resonance imaging techniques provide us with opportunities for examining the excess iron in the body. The phase changes across the blood vessels on gradient echo images depend on the susceptibility difference between the vessel and liver tissue, which can be used to quantify the iron concentration in liver. This susceptibility difference can be computed as below [2,3]:

$$\mathbf{K} = \frac{\Phi}{4\pi^2 \bullet \mathbf{TE} \bullet \mathbf{f_0}} = \sin^2(\theta) \bullet \Delta\chi$$

where $\Phi$ is the phase, TE is echo time, and $f_0$ is the transmitter RF frequency, and $\theta$ is the angle between the vessel axis and $B_0$. The susceptibility difference, $\Delta\chi$ (in emu/cm$^3$), is the slope of the K vs. $\sin^2(\theta)$ plot. Previous phantom studies [3] showed that the blood flow in liver should not influence the measured susceptibility. The simulations [3] showed that it is desirable to use isotropic pixels smaller than the diameter of the vessel. The purpose of this study was to estimate the measurement precision on normal human subjects.

**Materials and Methods:**

Six healthy people (Table 1) were scanned on a Philips 1.5T Intera Scanner. The study was approved by the Institutional Review Board, and informed written consent was obtained from each subjects. To estimate the reproducibility, Subjects 1 and 2 were scanned 5 and 4 times, respectively. Each repeat scan was conducted after repositioning the subject as well as the coil. For this study, the four-element body SENSE coil was positioned around a volunteer’s chest. Image data was acquired by using a 3D T1FFE sequence for inflow MR angiography with RF spoiling, T2 preparation, full flow compensation, ECG triggering and navigator gating and tracking (Slab thickness 120 mm; TE = 70 ms for T2 preparation; TR/TE= 7.1/4.0 ms, flip=30$^o$ and TFE factor = 30 for FFE readout; FOV=288, RFOV=80%, sampling pixel size = 1.5*1.5*1.5 mm$^3$). Navigator beam with a length of 7.0 cm was located to cross the diaphragm between liver and lung. Raw data was saved and post-processed by internally developed software written in IDL. Data from one coil element were analyzed, and all images were zero-filled to obtain 1.0*1.0*1.0 mm$^3$ reconstructed pixel size, and volumes of liver were traced out for background phase calculation. The background phase caused by inhomogenous field was obtained by a 3D complex curve fitting within the liver volume. Centerline of vessel was semi-automatically traced by using internally developed seed growing software. The susceptibility of the liver was calculated from the phase and centerline information of all identifiable branches of liver vessels (predominately veins) with a diameter 4 to 9 mm.

**Results:**

Effect of background-phase subtraction is shown in Figures 1 and 2. Reproducibility results are shown in Table 1. The background-phase correction significantly improves the precision of susceptibility measurement (Table 1). Variations across the 6 subjects are shown in Table 2. The range of $\Delta\chi$ in the normal subjects is 0.033x10$^{-6}$, which is much large than the uncertainty for an individual (<0.007x10$^{-6}$). Based on the relationship between the susceptibility and the liver iron concentration [4], the standard deviation in susceptibility of the two multiply scanned subjects corresponded to 0.06 and 0. 02 mg Fe/g wet tissue, respectively. The range of the susceptibility in the 6 subjects corresponded to 0.3 mg Fe/g wet tissue.

**Conclusions:**

The 3D T1FFE with cardiac trigger and navigator gating and tracking is a reproducible technique for measuring the magnetic susceptibility of the liver in normal subjects. The technique as is can also be used for patients with mild iron overload and does not require breath-holding.

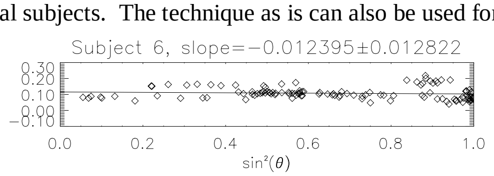


Figure 1: K vs $\sin^2(\theta)$ data and line fit before subtracting the background phase.

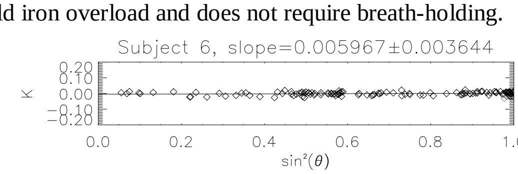


Figure 2: K vs $\sin^2(\theta)$ data and line fit after subtracting the background phase.

| Scan | $\Delta\chi(10^{-6})$ of Subject 1 | | $\Delta\chi(10^{-6})$ of Subject 2 | |
|---|---|---|---|---|
| | Phase correction | | Phase correction | |
| | No | Yes | No | Yes |
| 1 | 0.0104 | -0.0048 | -0.0290 | -0.0076 |
| 2 | 0.0232 | -0.0073 | -0.0132 | -0.0130 |
| 3 | -0.0280 | -0.0108 | -0.0196 | -0.0213 |
| 4 | -0.0493 | -0.0064 | -0.0118 | -0.0222 |
| 5 | 0.0644 | -0.0035 | - | - |
| Mean | 0.0041 | -0.0066 | -0.0184 | -0.0160 |
| s.d. | 0.0445 | 0.0025 | 0.0078 | 0.0070 |

Table 1: Reproducibility analysis on two normal volunteers.

| Subject | Age /gender | $\Delta\chi(10^{-6})$ | s.d.$(10^{-6})$ |
|---|---|---|---|
| 1 | 38/F | -0.0066 | 0.0025$^{(a)}$ |
| 2 | 10/M | -0.0160 | 0.0070$^{(a)}$ |
| 3 | 40/M | 0.0071 | 0.0038$^{(b)}$ |
| 4 | 45/M | 0.0314 | 0.0031$^{(b)}$ |
| 5 | 31/M | -0.0080 | 0.0028$^{(b)}$ |
| 6 | 40/M | 0.0060 | 0.0036$^{(b)}$ |
| Range | - | 0.0330 | - |

Table 2: Susceptibility results on 6 normal volunteers. The s.d. values were determined from (a) multiple measurements in Table 1, or (b) the uncertainty of the curve fit.

References:

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