Improving T_2* mapping at 7 T

W. Dou[1], R. Deichmann[2], O. Speck[1], and K. Zhong[1]

[1]Biomedical Magnetic Resonance, Otto-von-Guericke University, Magdeburg, Saxon-Anhalt, Germany, [2]Brain Imaging Center, Johann Wolfgang Goethe-University Frankfurt/M., Frankfurt/Main, Hesse, Germany

Introduction:

Previous studies at 7 T showed that brain T_2^* maps are closely related to the tissue iron distribution in iron rich brain regions [1]. However, stronger B_0 field inhomogeneities at 7T can decrease T_2^* and result in greater error in iron quantification. Deichmann et al [2,3] proposed a T_2^* correction method for the effects of the linear susceptibility gradients and showed good results at 3T. Due to stronger non-linear effects at 7 T, an improved correction method considering both linear and quadratic B_0 variations across the imaging slice was proposed. This new method was verified at 7 T and compared to the linear correction method.

Theory:

For a gradient echo sequence, the signal *S(TE)* at echo time (TE) can be written as $S(TE) = S_0 \cdot e^{-TE/T_2^*} \cdot \int P(z) e^{i\gamma \mathbf{G} z TE} dz$, where *P(z)* is the slice excitation profile and G is the through-plane susceptibility gradient. For small angle approximation, *S(TE)* corresponds to a Fourier transform of G and the signal correction factor *F(TE)* can be written as a function of *A(G·TE)*, which implies the additional signal decay due to through-plane gradients. When non-linear B_0 variations are considered, then the susceptibility gradient G can be expressed as $G_{qua}(z) = az + b$. The correction factor then is a function of both G and *P(z)*. For a Gaussian excitation pulse with pulse width 2*d*, it can be written as

$$F(TE) = \frac{\int_{-\infty}^{\infty} e^{(-\frac{2z^2}{d^2})} \cdot e^{\left[i\cdot\gamma\cdot TE\cdot(a\cdot z^2 + b\cdot z)\right]} \cdot dz}{\int_{-\infty}^{\infty} e^{(-\frac{2z^2}{d^2})} dz} = -\frac{e^{\left[\frac{\gamma^2 \cdot TE^2 \cdot b^2 \cdot d^2}{4(-2+i\cdot a\cdot\gamma\cdot TE\cdot d^2)}\right]} \cdot \sqrt{2}}{\sqrt{2 - ia\cdot\gamma\cdot TE\cdot d^2}} \tag{1}$$

Materials and Methods:

All experiments were performed on a 7 T MR scanner (Siemens MAGNETOM, Erlangen, Germany) using a 24 channel head array coil. A modified RF-spoiled 2D multiple gradient echo sequence (224x256 matrix, 0.78x0.78 mm^2 in-plane resolution; TR = 51 ms; flip angle = 20°) was employed for image acquisition with eight TEs (8, 13, 18, 23, 28, 33, 38, 43 ms). Three different slice thicknesses (1.0, 1.5, 2.5 mm) were chosen to investigate the effect of various degrees of through-plane dephasing. MATLAB and SPM5 were used for data processing.

Results and Discussion:

The three rows in Fig. 1 showed T_2^* maps acquired at the respective slice thicknesses, without correction (left), with linear correction (center) and with quadratic correction (right). From the T_2^* maps, three different ROIs (red rectangular areas) were selected for comparison and the corresponding T_2^* values were plotted in Fig. 2. The susceptibility gradients for the three ROIs were 130, 80 and 20 µT/m. For a small susceptibility gradient (20 µT/m), T_2^* values before and after correction gave similar results (32 ms) for a slice thickness of 1mm. For intermediate susceptibility gradient values (80 - 130 µT/m), T_2^* decreased with increased susceptibility gradient. Both linear and quadratic correction method gave improved T_2^* values as compared to that of the uncorrected T_2^* maps. Furthermore, the quadratic correction method gave a T_2^* value around 28 ms for a slice thickness of 1 mm and a susceptibility gradient of 130 µT/m, while the linear correction method only gave a T_2^* value of 23 ms. Therefore, the inclusion of a quadratic term in the susceptibility gradient correction does improve significantly the result of the T_2^* correction at 7 T. On the other hand, certain regions with T_2^* drop out can not be corrected, even with the new method. Those regions suffer from stronger susceptibility gradients (> 200 µT/m) and may be corrected with combination of different acquisition strategies that need to be further investigated.

Conclusion:

The quadratic correction method is more robust in areas suffering from moderate to intermediate susceptibility gradient distortion. Therefore, this new method should allow for more reliable T_2^* mapping at 7 T for in vivo studies.

Acknowledgement:

This work is supported by the European Union sponsored CBBS NeuroNetwork project (KZ).

Reference:

[1] Yao B. et al. NeuroImage 44:1259-66 (2009). [2] Baudrexel S. et al. MRM 62:263-8 (2009).
[3] Preibisch C.et al. MRM 60:908-16 (2008).

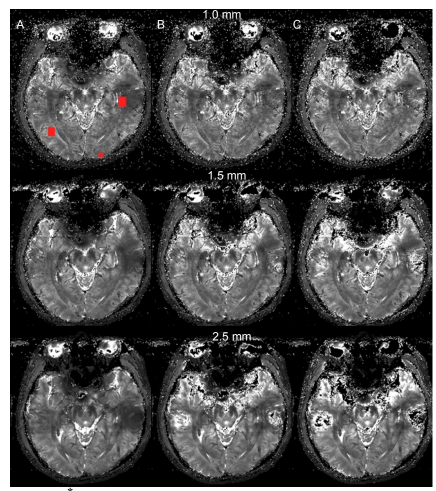

Fig. 1: T_2^* maps with different slice thicknesses (1, 1.5 and 2.5 mm). A) no correction; B) linear correction; C) quadratic correction. The three ROIs are shown with red rectangles.

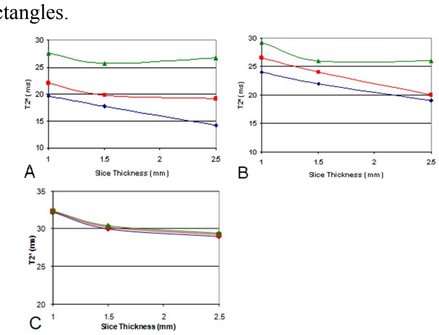

Fig. 2: Comparison of T_2^* values before (dark blue) and after linear (red) and quadratic correction (green) for ROI1 (A), ROI2 (B) and ROI3 (C) with the slice thicknesses of 1.0mm, 1.5mm and 2.5mm.