<u>**Elimination of susceptibility-induced distortion in the T2*-decay curve with an improved fitting procedure**</u>

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Introduction

Quantitative T2* mapping provides important index for characterizing SPIO-based post-contrast tissue properties [1], BOLD signal detectability [2] and iron concentration [3]. Although T2* mapping could be obtained by fitting the TE-dependent signal intensities, background susceptibility field gradients, which are known to be the source of echo-shifting effect and TE-shifting effect [2, 4], may introduce systematic errors in fitting the monoexponential T2*-decay curve. Moreover, the shapes of T2* decay curves (e.g., monoexponential, biexponential, or non-exponential) may potentially be altered by a unique signal-dropout artifact, depending on both field inhomogeneity patterns and the acquisition paradigms. In this study, we proposed an improved fitting procedure to significantly enhance the accuracy of T2*-mapping by correcting for the systematic TE-shifting effect and the unique signal-loss artifact from echo-shifting. Our phantom and human results suggest that the accurate T2* mapping can be substantially benefit from our proposed T2*-fitting procedure especially at regions with varied background field gradient.

Methods

In a previous report [4], quantification of the TE-shifting effect could be achieved with equation 1 below, where TE_0 is the designated echo time, ESP and SGP are the echo-spacing and susceptibility field gradient along the phase-encoding direction, respectively. This equation also demonstrates that the deviation of TE value (ΔTE) is linearly proportional to TE_0 and related to the k-space energy peak location (Δky), which records the echo-shifting effect in the original 2D k-space data. The SGP map can be calculated directly from susceptibility field map with scaling factor Q, where $Q = 1 + \gamma \cdot ESP / 2\pi \cdot FOV \cdot SGP$ [2]. ΔTE and Δky maps, therefore, can be subsequently produced at particular designated TE based on equation 1. Since Δky contains the information of k-space energy peak location, a threshould should be set according to matrix size to judge whether echo energy peak was shifted completely outside of the k-space acquisition window, such that data degraded by the signal-loss artifact from echo-shifting could be excluded during the process. Afterwards, the corrected TE value for all pixels can be calculated by correcting TE values with ΔTE and assigned into T2*-fitting procedure.

$$\Delta TE = \frac{-SGP \times TE_0 \times ESP}{SGP \times ESP + \dfrac{1}{\gamma \times FOV_{PE}}} = \Delta ky \times ESP \quad \cdots\cdots [1]$$

A silicone gel phantom was scanned on a GE Signa 3.0T system to examine the effectiveness of the proposed method for accurate T2* mapping. 100-TE multi-TE EPI images were obtained with the following scan parameters: 240 mm FOV, matrix size 64×64, 3 slices, echo spacing time 0.592 ms. The first designated TE was 28 ms, with 1 ms step. 10 datasets were acquired with varying shimming conditions for different background field gradient situations (including one on-resonance situation) in unit of Hz/mm. The data from healthy volunteers were acquired at a 1.5T MR system (GE Signa, Milwaukee). The image parameters were 240 mm FOV, 96 by 96 matrix size, 8 slices, 96 TE values ranging from 42.3 to 113.94 ms in 0.752-ms steps and echo spacing time 0.752 ms.

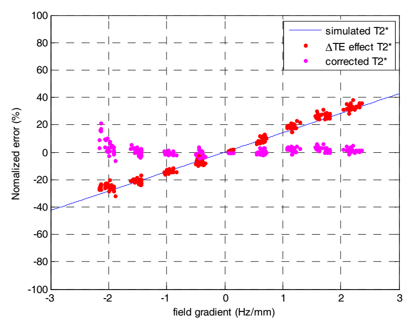

Fig. 1 Uncorrected vs. corrected results.

Results

Figure 1 shows the percentage error in T2* value before/after correction for TE-shifting effect for the phantom experiments, where the dot represents the measurement result and blue line is the calculation result from theoretical simulation assuming conventional T2*-fitting without using our correction scheme (each dataset includes 27 pixels across 3 slices). Comparison is based on data acquired under on-resonanace situation, which is viewed as the gold standrad T2* values. The red and magenta dots illustrate the T2* results derived without and with using our proposed fitting procedure, respectively. Figure 2(a,b) shows the T2* maps from a chosen slice with and without echo/TE-shifting correction, repectively, and figure 2c is the absolute difference between figs. 2a and 2b. It can be seen that the accuracy of T2*-fitting is hampered particularly in the frontal lobe, which shows substantial background field gradient as seen in Figure 2d. The improved T2*-fitting procedure is anticipated to be especially effective in brain regions affected by these pronounced local field gradients.

Discussion and Conclusion

When there exists significant background susceptibility field gradients in EPI data, the T2* values derived from conventional fitting procedures may be distorted. To achieve accurate T2* mapping, the systematic TE-shifting effect should be corrected, and the data points shifted out of acquisition window should be excluded from T2*-fitting procedure. It should be noted that, if the susceptibility field gradient is very strong, then most of the data will be excluded, resulting in insufficient data points useful for T2*-fitting. In this case, a larger k-space matrix size should be chosen for acquisition to provide more useful time points for T2*-fitting. In conclusion, the improved T2*-fitting procedure has a much better tolerance to field inhomogeneities and has potential for many applications relying on accurate quantitifaction of T2* values.

References

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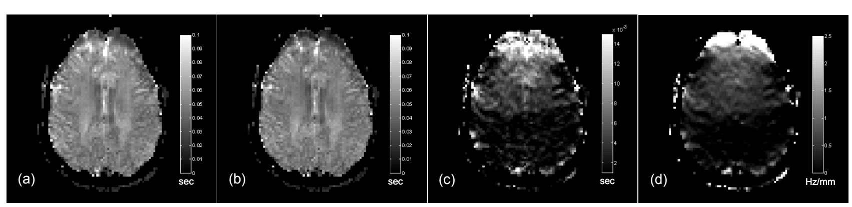

Fig 2 (a) Uncorrected T2* map. (b) Corrected T2* map. (c) Difference between a and b. (d) Background field gradient map.