Accurate T2 Mapping with Dual Echo-FSE: Effect of Phase Encoding Profile Orders

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Purpose: Recently, it has been reported that T_2 qMRI with dual-echo fast spin echo (DE-FSE) can be inaccurate as much as 10% (1). Here we test the hypothesis that the reported T_2 discrepancy relative to the gold standard --32 echo CPMG pulse sequence (2)-- could be a DE-FSE echo train effect that is secondary to using different phase encoding profile orders for the first and the second echo. A T_2 qMRI algorithm, which corrects for this effect is developed and tested with the ACR MRI accreditation phantom and in the human brain.

Theory: The pixel values for echoes 1 and 2 of a DE-FSE train lead to the following modified T_2 mapping formula:

$$T_{2,(i,j,sl)}^{(A)} = \frac{TE2_{eff} - TE1_{eff}}{\ln\left(\frac{pv_{(i,j,sl)}^{Acq\_1}}{pv_{(i,j,sl)}^{Acq\_2}} \frac{\Delta V_{(i,j,sl)}^{Acq\_2}}{\Delta V_{(i,j,sl)}^{Acq\_1}} \right)} \qquad \textit{Eq. } 1$$

where $pv_{(i,j,sl)}^{Acq\_1,2}$ are the experimental pixel values for echoes 1 and 2 and the voxel volumes are functions of the voxel response functions, a.k.a. voxel sensitivity functions (3):

$$\Delta V_{(i,j,sl)}^{Acq\_1,2} = \iiint_{\{\text{Infinite space}\}} VSF^{(Acq\_1,2)}\left(\vec{X}_{(i,j,sl)} - \vec{x}\right) d^3x \qquad \textit{Eq. } 2$$

These integrals depend on the phase encoding profile order and also on T_2. If different phase encoding profile orders are used for echoes 1 and 2, as is usually the case for obtaining shortest TE1eff and long TE2eff, then a correction to the standard T_2 mapping equation results (*Eq.* 1).

Experimental Methods: The ACR MRI accreditation phantom and a research subject were scanned at 1.5T using a dual echo FSE pulse sequence implemented with centric and linear profile orders for echoes 1 and 2 (see *Fig.* 1) respectively and the results were compared to those of references (1) and (2) for the ACR phantom and the human brain respectively. The ACR phantom contains 10mM and 20mM $NiCl_2$ solutions with reported T_2 values of 135ms and 70ms respectively.

Results: The centric and linear phase encoding profile orders (*Fig.* 1 top) lead to measurably different voxel sensitivity functions (*Fig.* 1 bottom). T_2 maps with and without the profile order correction are very similar in appearance but are quantitatively different (difference T2 map: bottom image in *Fig.* 2): T_2s for WM were approximately 90ms without correction and 80ms with the correction (*Fig.* 2, top and middle, respectively). Similarly, for gray matter the T_2s decreased from 110ms to 100ms when the profile order correction was applied. Likewise, for the ACR phantom T_2 values (*Fig. 3*) 69±4ms and 134±6ms are in excellent agreement with those reported (1) with the CPMG-32 echoes gold standard pulse sequence. The values without correction were 74±4ms and 154±8ms, again in excellent agreement with the ones reported (1) for DE-FSE.

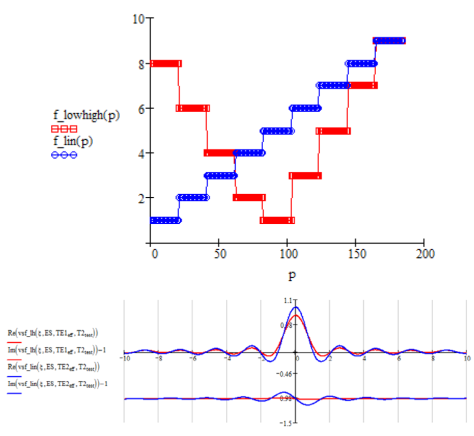

Figure 1

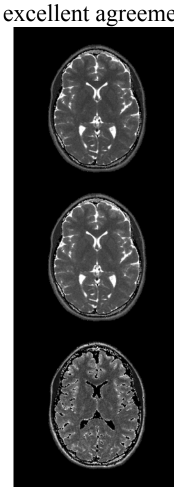

Figure 2

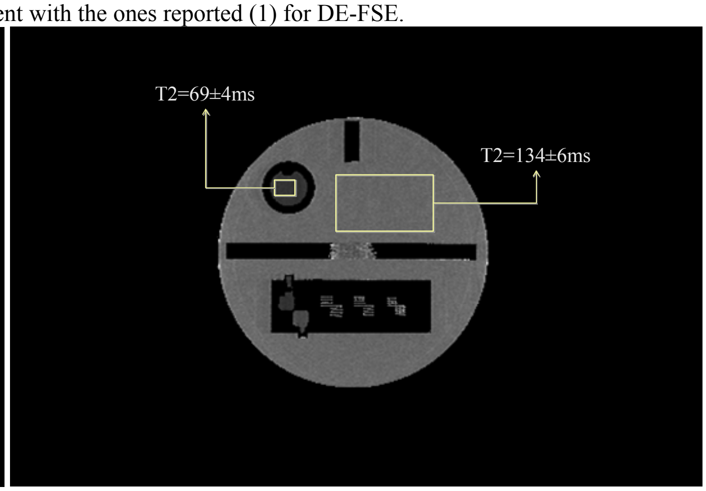

Figure 3

Conclusion: Accuracy of T_2 qMRI with the DE-FSE pulse sequence can be improved by correcting for profile order effects. This work could have implications for large scale studies that use DE-FSE instead of CPMG-32 echoes pulse sequences due to time and anatomic coverage constraints.

References

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