Comparison of Different EPI-based Approaches to Measure T2' in Human Brain for the Purpose of Oxygenation Measurements

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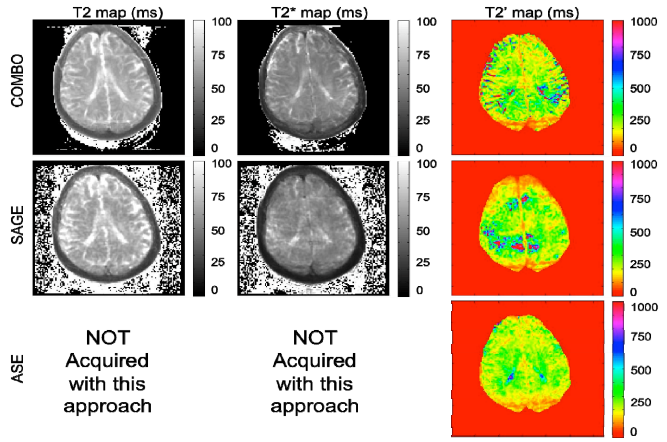
Introduction

T2* is an important parameter to study the level of blood oxygenation or iron content in the brain. However, while sensitive to magnetic susceptibility sources, T2* also depends on several other parameters that can affect the measurements. In order to study pathologies such as stroke or cancer, the effect of the transverse relaxation time T2 must be removed [1]. A parameter called T2' is derived according to the formula 1/T2*=1/T2+1/T2'. T2' imaging can be performed in three different manners: (1) Using a subtraction of T2 from T2* relaxation rates that are derived from separate T2- and T2*-weighted multiecho sequences. (COMBO method); (2) Using an asymmetric spin echo sequence where the position of the 180° refocusing pulse is progressively moved while keeping the readout at a fixed echo time (ASE method) [2] (3) Using a single sequence that combines multiple echoes before and after a 180 refocusing pulse (SAGE method) [3]. Methods 1 & 2 have the problem of being slower and hence more sensitive to motion and misregistration. Method 2 is supposed to be insensitive to water diffusion effects. Method 3 might suffer from an achievable lower spatial resolution. The aim of this study was to compare the three approaches in the human brain.

Fig 1: Parametric maps (T2, T2, and T2') obtained with the three methods in one subject*



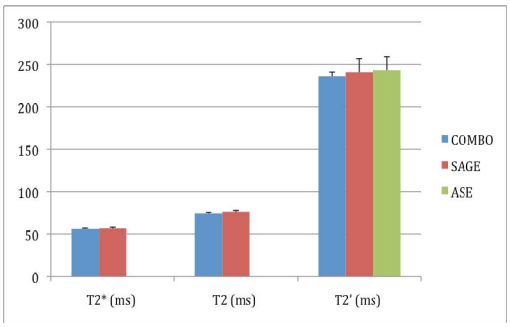


Fig 2: Mean and standard deviation of T2,T2 and T2' averaged over the 4 volunteers*

Material and Methods: All imaging was performed at 3T using a GE Signa Excite 15.0 whole-body scanner (GE Healthcare Systems, Milwaukee, WI) with gradient strengh of 4G/cm slew rate 150 T/m/s and an 8-channel head coil. Four subjects were scanned using the following protocol:

-A higher-order shimming procedure was used to reduce B0 heterogeneity prior to the scans.

-COMBO method: Repetition of separate gradient-echo EPI and spin-echo EPI sequences (FOV=22*22cm2, 128x128, TR=5000ms, ST=2mm, 20slices, 4shots) with variation of the echo time (TE=15-25-35-45-55ms). T2* and T2 maps were obtained using a non-linear exponential fit of the gradient echo (spin echo) signal, respectively. T2' was computed as 1/(1/T2*-1/T2) for each voxel.

-ASE method: Repetition of a spin-echo EPI sequence (FOV=22*22cm2, 128x128, TR=5000ms, ST=2mm, 20slices, 4shots, TE=110ms) with variation of the asymmetric echo time (ΔTE=15-25-35-45ms). T2' was obtained directly using a non-linear exponential fit of the ASE signal.

-SAGE method: A single EPI sequence with 4 gradient-echoes (TE=12-30-68-85ms) and 1 spin-echo (TE=110ms) [4] (FOV=22·22cm2, 96·96 interpolated to 128·128, TR=5000ms, ST=2mm, 20slices, 4shots). T2* and $T2^*_B$ (T2* acquired after the 180 degree pulse during the regrowth of the signal) were obtained using a non-linear exponential fit of the first 2 gradient echoes (TE=12-30ms) and 3 last echoes (TE=68-85-110), respectively. T2 was computed as $2/(1/T2^*+1/T2^*_B)$ and T2' as $2/(1/T2^*-1/T2^*_B)$. Regions of interest were manually drawn over the entire brain. Voxels with T2'>1000ms were excluded from the analysis. Student t-tests (after assessment of variance homogeneity) were used to assess differences (*:$p<0.05$).

Results: Parametric maps from one subject are presented as Figure 1. One can clearly see the overall agreement between the three methods. The T2' maps show similar global information. However all three maps contain different amount of rejected pixels (i.e. T2'>1000ms). These pixels correspond to the presence of liquid or vessels in the COMBO and ASE approaches. However a non physiologic origin (possibly caused by the interleaved EPI acquisition) in the SAGE method was present. Mean and standard deviation of T2, T2*, and T2' averaged over the whole brain and for the 4 subjects are presented in Figure 2. A brain T2 of about 75 ms was found with both the COMBO and SAGE approach whereas T2* was about 55 ms. These values are in agreement with previous studies on transverse relaxation [5]. No significant difference was found between the T2' values.

Conclusion

This study suggests that the three different approaches give similar T2' values in the healthy human brain. They however showed spatial differences. The highest quality maps were obtained with the ASE method. This approach, however, gives only information about the T2' values with no distinction between T2 or T2* origin. The SAGE approach, while containing some spatial artefacts, does not require registration and could be used in a dynamic approach with high time resolution.

References: [1] S Siemonsen et.al, radiology, 2008. [2] H An and W Lin, MRM, 2003. [3] J Ma and Wherli, J Magn Reson B, 1996. [4] Newbould, et al. Proc ISMRM 2007, p1451. [5] Peran et.al, JMRI, 2007.