Fast brain imaging with spin echo and spatio-temporal correlation (k-t) approaches for distortion-free fMRI

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Introduction

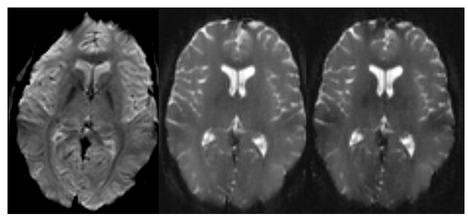
As imaging at field strengths of 3 Tesla and above becomes more widespread, the propensity of echo planar imaging (EPI) to signal loss and image distortion increases, and with it the motivation for a practical alternative for functional MRI. Fast, or turbo spin echo (TSE) based pulse sequences have been proposed [1], but the challenges of adequate temporal resolution and avoiding excessive specific absorption rates (SAR) must be addressed for these techniques to become acceptable for routine brain mapping in humans. This study demonstrates the promise of single shot TSE, combined with parallel imaging using spatio-temporal correlation (k-t) approaches [2], for anatomically accurate T_2*-weighted (T_2*W) or T_2W blood oxygen level dependent (BOLD) fMRI in the human brain.

Methods

T_2*W was achieved in TSE images by a delay, τ, between the excitation and refocussing (α) RF pulses, with $\alpha = 100^0$ and appropriate gradient pulses in the frequency encoding direction to remove one echo group from the acquisition window [3]. For faster imaging, TSE was also combined with the k-t approach with reduced acquisition matrices. Images were acquired at 3.0 Tesla with an eight channel head coil (Philips Medical Systems, Best, Netherlands), using the following parameters: matrix = 128, FOV = 240 mm, slice thickness = 3.5 mm with 0.5 mm gaps, phase encoding AP; partial Fourier of 77 % for EPI; six dummy echoes for TSE. Under sampling rates of k-t=12 and k-t=16 were employed in TSE imaging. In a separate experiment gradient echo EPI and T_2*W - TSE images were acquired during finger tapping in a right handed subject in five blocks of 30 seconds on / off, TR = 2800 ms for both fMRI acquisitions.

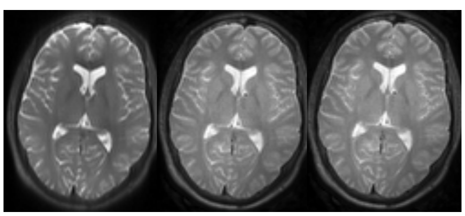
Results

Figure 1 shows TSE and EPI images with similar T_2* weighting. The TSE images are free of distortion even in areas with very short T_2* such as the frontal lobe. Figure 2 shows TSE images with significantly reduced data acquisitions by means of a k-t approach and k-t SENSE reconstruction. Figure 3 is a comparison of EPI and T_2*W TSE fMRI results from a finger tapping task. Activation maps are overlaid onto the original images.



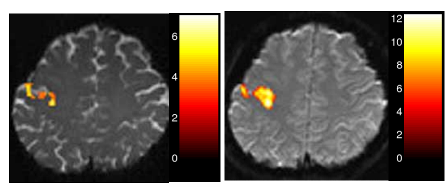
a) EPI TE = 30 ms b) TSE τ = 20 ms c) TSE τ = 30 ms

Figure 1 Echo Planar and T_2*W TSE images The slice position is identical. The distortion of the frontal cortex in the EPI is not present in the TSE images.



a) full data TR = 944 ms b) k-t = 12 TR = 213 ms c) k-t =16 TR = 199 ms

Figure 2 TSE images with k-t acquisitions Data reduction (k-t) factors and minimum TR times for one slice are shown.



a) TSE (τ = 30 ms) b) EPI (TE =30 ms)

Figure 3 Brain activation during finger tapping acquired with a) T_2*W TSE and b) gradient echo EPI. p=0.05, FDR corrected.

Discussion

The anatomic fidelity of TSE images (*figure 1*) may be combined with any degree of T_2* weighting, by selecting the appropriate τ. This opens up numerous possibilities, including slice-selective T_2* weighting to optimise BOLD contrast throughout the brain and T_2* mapping. T_2*W BOLD contrast upon functional activation has been demonstrated using the TSE pulse sequence (*figure 3*). While the maximum achievable SENSE factor is limited by coil geometry, the k-t approach lends itself to fMRI acquisitions [2] and images shown here demonstrate data reductions as great as 16 with good image quality (*figure 2*). Reduced echo train lengths also reduce SAR. Further possibilities include combining TSE imaging and k-t acquisitions for T_2 based BOLD studies. Further work is necessary to investigate the temporal fidelity of k-t acquisitions and to optimise these approaches for fMRI, considering issues such as the parameters and frequency of k-t training data acquisitions.

References

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