Fast Whole-Brain Perfusion fMRI using 3D GRASE Slab-Selective IR with background suppression

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Introduction

ASL is rapidly advancing in the field of functional magnetic resonance imaging. Such perfusion methods show many advantages over current BOLD fMRI, e.g. better activation localization, better consistency in the interpretation of results, due to direct perfusion measurement, possibility of quantification, etc. Despite many advantages ASL is still not able to completely replace EPI BOLD imaging, mainly due to strong limitations in time resolution and spatial coverage of most ASL methods. However, in numerous cases of neuroscience research whole brain coverage and good temporal resolution is essential. In this paper a perfusion sensitive IR technique was combined with a fast 3D GRASE readout and background suppression to overcome these limitations. This relative perfusion method is compared with results from standard BOLD fMRI.

Materials and methods

A pulsed FAIR ASL sequence with 3D GRASE readout as reported previously (1) was modified to facilitate the same spatial coverage and time resolution as standard EPI BOLD sequences typically used in the neuroscience community. To this aim the scheme was reduced to a slice selective IR experiment (omitting the control tag) and adding two additional selective hyperbolic-secant pulses for background suppression. The inversion times of these selective inversion pulses were optimised to null static tissue with T1 values of 1000ms and 2000ms at readout time (2). This set-up makes it possible to measure relative perfusion changes with temporal resolution in the range of 2s with large spatial coverage. The main additional 3D GRASE ASL parameters were: 26 partitions, TR=3.0s, 64x64 matrix, resolution=4x4.4x4.4mm, FoV=280x140mm, 5/8 partial Fourier, BW=2704Hz/pixel, TE=23ms centric reordered, TI=1200ms.
For comparison with standard BOLD fMRI a T2*-sensitive 2D-EPI experiment was performed with comparable main parameters: 26 slices, TR=3.0s, 64x64 matrix, resolution=4x4.4x4.4mm, TE=55ms, FoV=280x280, BW=2704Hz/pixel.
Both sequences were used to conduct a blocked finger tapping motor task experiment with volunteers in a 1.5T Siemens Sonata Scanner. The task consisted of 4 blocks of 30s of bi-handed finger movement alternating with 30s resting state. This resulted in 90 image volume acquisitions for perfusion and BOLD fMRI, respectively. Data series were evaluated by smoothing (8mm gaussian kernel), followed by normalisation to MNI space, highpass filtering, global scaling and regression analysis including t-test evaluation. Statistical analysis was performed with SPM2.

Results and Discussion

In Fig 1. a side by side comparison between a whole brain ASL GRASE experiment and a standard BOLD EPI is shown. The cut-off threshold was chosen at $p=10^{-8}$ (corrected for accidental occurrences of activity). For the motor experiment both methods yielded highly significant results for all known motor responses. The ASL technique showed a perfusion enhancement within the motor cortices during activation of approx. 20% while the typical peak BOLD effect was determined to be about 4-5%. GRASE ASL generally yielded activation maps with better spatial confinement of probable activations to brain parenchyma. In Fig.2 the time courses of the maximum effect for both techniques are shown for one volunteer. Due to lower SNR of the ASL images the time courses show more noise than EPI BOLD. This results in lower p-values in the activation maps for ASL. EPI BOLD images however also showed some probably artifactual activations possibly due to the depiction of the reaction of large veins to the activation task.

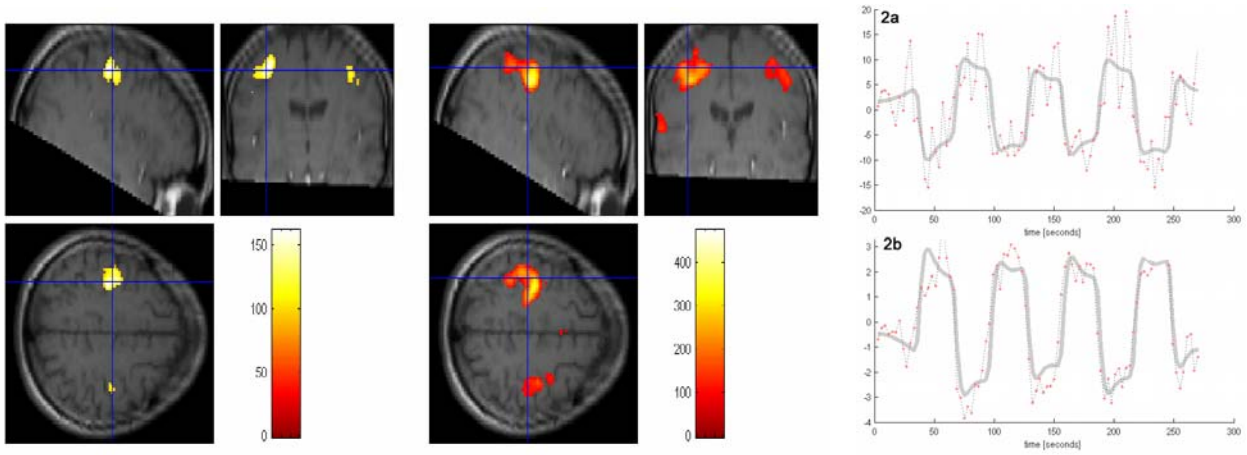

Fig 1: Overlay of whole brain t-test activation maps on a normalized T1 anatomy. Left: result from 3D GRASE (ASL) perfusion series, Right: EPI BOLD fMRI experiment with same time resolution. (cut-off threshold $p=10^{-8}$ for both methods)
Fig 2: Time courses of the voxel with maximum effect a) relative Perfusion changes measured by 3D GRASE ASL, b) Corresponding BOLD changes from standard 2D EPI.

Conclusions

The reduced ASL scheme with 3D GRASE readout proposed here is capable to achieve at least the same spatial coverage and temporal resolution as standard EPI without major drawbacks. This can be a promising approach to substitute standard fMRI experiments with perfusion fMRI in numerous cases where whole brain coverage is required with relatively high temporal resolution. In many cognitive experiments involving critical regions in the vicinity of magnetic inhomogeneities (e.g. frontal cortex or amygdala) where BOLD fMRI cannot be reliable such a technique might be especially useful.

References:

(1)Guenther, et al. (2005), MRM 54, 491-498, (2) Ye et al. (2000), MRM 44, 92-100