3T Pseudo-continuous ASL Perfusion fMRI with Background-Suppressed Single Shot 3D GRASE During Memory Encoding

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Introduction

We have previously demonstrated that single shot 3D GRASE (1) using continuous ASL (CASL) at 3T generates perfusion images comparable to those obtained with a 2D EPI readout, albeit with better coverage in the orbito-frontal cortex (2). Recently, the performance of the sequence has been further improved by implementing a more efficient pseudo-continuous ASL (p-CASL) approach for flow driven adiabatic inversion (3) that is compatible with body coil transmission and array receiver, and by adding inversion pulses to suppress static background signal (4). The performance of the improved sequence was evaluated by comparison with BOLD fMRI during a complex visual scene encoding task (5).

Materials and Methods

Studies were performed on a 3T Siemens Trio scanner using the product 8-channel head receiver array. Seven healthy volunteers were scanned using both ASL and BOLD fMRI during the same session. The memory encoding paradigm was administered as a blocked design consisting of task/control cycles of complex visual scenes or a scrambled scene control stimulus. Subjects were instructed to remember the scenes but only attend to the scrambled scene. The duration of the blocks was 36 sec for BOLD and 2.25 min for ASL. Total duration was 9.25 min for each scan. The p-CASL background-suppressed 3D GRASE is shown in Fig. 1. The imaging slab covered the temporal lobes. Imaging parameters were: resolution=4mm isotropic, FOV=250x204x48 mm^3, 12 nominal partitions with 33% oversampling, 5/8 partial Fourier, measured partitions=10, matrix size=64x52, BW=3004 Hz/pixel, gradient-echo spacing=0.4msec (with ramp sampling), spin-echo spacing=26msec, total read-out time=270msec, effective TE=43msec, refocusing flip angle=162° and TR=3.75 sec. The p-CASL pulse (2) consisted of 1280 selective RF pulses, played sequentially, at equal spacing, for a 1.2sec labeling duration. Each RF pulse was shaped as a Hanning window (peak B_1=53mG, duration=500 µsec and G=0.6 G/cm). For the control pulse, the RF phase alternated from 0 to 180°. The post-labeling delay was 400msec. Two hyperbolic secant inversion pulses (15.35 msec duration and 220 mG RF amplitude) were added with inversion times of 1590msec and 380msec, respectively, for background suppression (BS). The first pulse was applied selectively to the imaging slab while the second pulse was non-selective. The p-CASL pulse was placed in between the two BS pulses. Bipolar gradients (b=5sec/mm^2) were added between the excitation and the first refocusing pulse of the GRASE readout to suppress intravascular signal. 72 perfusion images were obtained by subtraction of tag and control (after discarding 4 dummy scans) and smoothed using a 12x12x8 mm^3 Gaussian kernel. BOLD data were acquired using a 2D GE-EPI sequence with resolution=3mm isotropic, FOV=192x192mm^2, matrix=64x64, 40 slices, TR=3sec, TE=30msec. Anatomical images were also acquired with a MPRAGE sequence and used for coregistration and normalization with a standard template brain. For both ASL and BOLD data, voxel-wise statistical analysis was performed using SPM2 for each individual subject followed by a group inference using the random effect model. Group activation maps were compared.

Results and Discussion

The number of BS pulses was limited to two due to SAR considerations, yielding a suppression of gray and white matter of 95% while CSF was suppressed to 20% of the original signal. The BS increased the temporal SNR of the ASL series from 1.8 to 9.6 (measured in a series of 40 pairs in one subject, using the global signal difference tag-control). Fig. 2 depicts perfusion maps, showing high signal in the region of the hippocampus. ASL (Fig. 3a) and BOLD (Fig. 3b) group maps showed activation in visual association cortex and extending forward to the hippocampus. The ASL activation appears to be more localized than the BOLD activation, which is likely due to the different physical parameter measured, perfusion in brain parenchyma instead of less localized venous response which may have a more global distribution away from the area of activation. Individual ASL maps showed activity in the hippocampus with peak T values from 1.96 to 7.07. The peak T value in this region was higher in the individual BOLD activation maps with a range [1.83 - 10.65]. However, activation was stronger in the group maps obtained from the perfusion data than the BOLD data (Tpeak = 8.68 vs 5.48), which is consistent with previous results (6). The activation in the BOLD group map did not survive FDR correction, while the FDR-corrected (p=0.05) ASL group map showed suprathreshold activation in the left hippocampus (Fig. 3c).

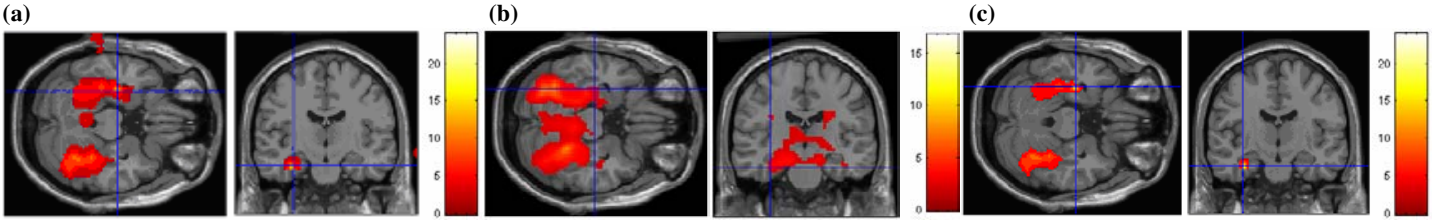


Fig. 3: Talairach-normalized group t-maps (n=7): (a) ASL; (b) BOLD (t>1.94, p<0.05 uncorrected); (c) ASL (t>3.7, FDR=5%).

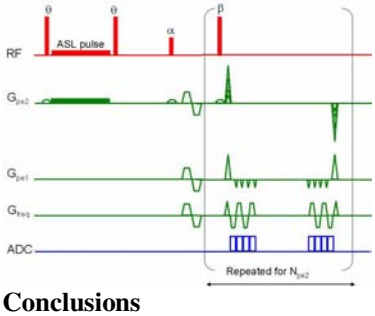
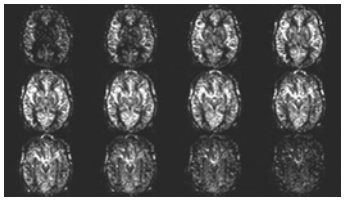


Figure 1: Pulse sequence diagram, showing the background suppression (θ) and p-CASL pulses, added to the single shot 3D GRASE readout.

Figure 2: Perfusion (tag-control) map.



Conclusions

ASL perfusion-based fMRI was used to detect activation of the hippocampus during a memory encoding task. Perfusion data were compared with BOLD results. Perfusion fMRI yielded stronger group activation, consistent with prior observations for sensorimotor tasks.

Bibliography

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Acknowledgments

NS045839, DA015149, BCS-0224007 and P41-RR02305.