Simultaneous Acquisition of Gradient Echo / Spin Echo BOLD and Perfusion with a Separate Labeling Coil

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INTRODUCTION

Arterial spin labeling (ASL) to measure cerebral blood flow (CBF) complements blood oxygenation level dependent (BOLD) contrast with a measure that is more quantitative and has better specificity to neuronal activation [1]. Recent advances improve low signal-to-noise ratios (SNR) of ASL by using a separate labeling coil to improve arterial labeling efficiency and to minimize magnetization transfer effects [2,3]. While the CBF contrast is better aligned with neuronal events [4] and more reproducible [5] than BOLD, simultaneous ASL and spin echo (SE) BOLD have not been compared. Relative to gradient echo (GE) BOLD, SE BOLD is less biased to draining veins and is more localized to intravascular space than extravascular regions [6]. We present a new pulse sequence that simultaneously acquires ASL with a separate labeling coil, gradient echo BOLD and spin echo BOLD. Simultaneous acquisition reduces inter-scan variability to improve evaluation of each contrast's relative specificity and reproducibility. Furthermore, it facilitates studies that would benefit from complementary measures.

METHODS

Image Acquisition: Data were acquired on a Siemens 3T TIM system utilizing an EPI sequence programmed in the Siemens IDEA environment and consisting of 3 readouts (Fig. 1). Arterial blood was labeled with a home-built butterfly labeling coil [2] (labeling duration of 3 s, post-label delay of 700 ms) and control and labeled images were interleaved. Following a 90° excitation, two acquisitions for CBF and gradient echo BOLD were acquired at short and long TE, respectively. After a subsequent 180° refocusing pulse, a symmetric spin echo BOLD acquisition was acquired (5 ascending slices, TR=4500 ms, TE1/TE2/TE3 = 12/35/105 ms, 3.43 x 3.43 x 5 mm resolution with 75% k-space coverage). Echo times were optimized for each contrast; CBF utilized the shortest possible TE to minimize BOLD contamination, GE BOLD matched TE to grey matter T2* and SE BOLD readout is symmetric about the echo (to minimize extravascular sensitivity) at a TE close to grey matter T2. Visual stimulus was presented using a block design with a flashing checkerboard covering 8 radial visual field degrees and reversing contrast at 8 Hz. Each scan consisted of two 63 second fixation blocks interleaved with two 63 second visual stimulus blocks. Additionally, a T1-weighted anatomical image was acquired using an MPRAGE sequence with 1 mm^3 resolution.

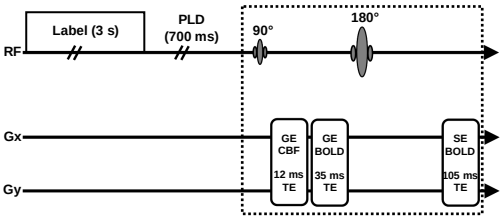

Fig. 1: Simultaneous sequence acquires CBF, GE BOLD and SE BOLD after following a 3 second label and 700 ms post-label delay (PLD).

Analysis: After motion correction, control and labeled images were subtracted and quantified [3] for CBF and averaged for SE and GE BOLD. Next, all data were coregistered to the high resolution anatomical image, normalized to an MNI template, spatially smoothed (5 mm FWHM kernel) and statistically analyzed using SPM2 (Wellcome Department, University College of London, London, UK). Activation maps were corrected for a false discovery rate (FDR) using a threshold of 0.05 [7].

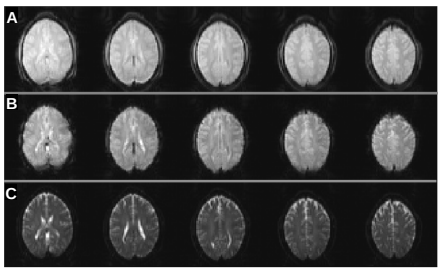

Fig. 2: Simultaneously acquired (A) CBF , (B) GE BOLD and (C) SE BOLD data.

RESULTS AND DISCUSSION

Images for each contrast show the expected contrasts of minimal T2/T2* decay for echo 1, T2* weighting for echo 2 and T2 weighting for echo 3 (Fig. 2). Activation maps also reflect the expected trend for each contrast. Specifically, CBF shows the most localized activation, reflecting the highest specificity and lowest sensitivity of the 3 contrasts (Fig 3A). In contrast, GE BOLD shows the largest activation region, consistent with expectations of high sensitivity (Fig 3B). SE BOLD demonstrates a compromise of the features of CBF and GE BOLD; while GE BOLD is sensitive to extravascular susceptibility, SE BOLD is known to be dominated by intravascular sensitivity, consistent with more localized activation (Fig. 3C). Still, SE BOLD has higher SNR and is more sensitive than CBF. Time courses (Fig. 4) reflect mean percent signal changes of 71.78%, 1.16% and 1.17% for CBF, GE BOLD and SE BOLD, respectively.

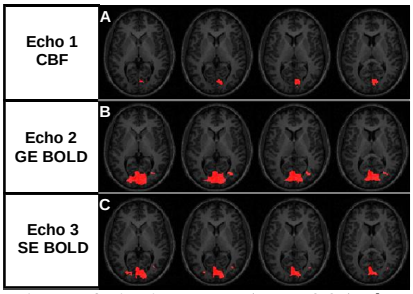

Fig. 3: Activation maps (FDR<0.05) show expected localization and sensitivity for each contrast.

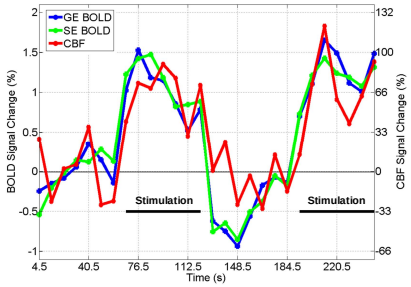

Fig. 4: Time courses for CBF, GE BOLD and SE BOLD.

CONCLUSION

This work presents a new sequence that simultaneously acquires CBF, GE BOLD and SE BOLD. Our sequence also uses a separate labeling coil to improve CBF SNR and sensitivity. Images show expected weightings and activation maps are consistent with known qualities of each contrast. Next, this sequence can be applied to compare intra- and inter-session reproducibility without inter-scan variability that confounds comparison using separate acquisitions for each contrast. Furthermore, scanning time can be significantly reduced relative to traditional protocols.

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