CASL Perfusion MRI with Non-segmented Low Flip Angle 3D EPI

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Introduction

Several arterial spin labeling (ASL) perfusion methods based on 3D imaging have been demonstrated (1-4) recently. ASL methods based on 3D imaging have the advantages of simultaneous and complete sampling of the tissue volume of interest. Simultaneous excitation of the whole imaging volume eliminates the slice dependent variation of the perfusion signal that accompany multi-slice methods due to differences in acquisition delays (5). Sampling of the imaging volume without gaps can provide better reproducibility in longitudinal ASL based fMRI studies. Previous 3D ASL perfusion studies have all been based on the acquisition of spin-echo trains refocused by large flip angle (160-180^o) pulses. However, application of closely spaced high flip angle pulse trains can lead to high SAR, especially at high field strengths. Therefore, in this work, we assess 3D continuous ASL (CASL) perfusion imaging using a train of low flip angle EPI readouts and compare its performance with multi-slice 2D CASL.

Method

Six volunteers were scanned under an NIH approved IRB protocol using a 3.0 T MRI scanner (GE, Signa Excite III). The body RF coil was used for excitation and the 8 channel brain array coil was used for signal reception. Continuous labeling of arterial blood flowing in the carotid and vertebral arteries was accomplished using a separate surface labeling coil (two 6.5 cm X 4.5 cm rectangular loops) placed on the neck (2). In this work, RF power to the neck labeling coil was applied to using the second transmit RF channel of the scanner modified to incorporate a gated, low power RF amplifier and an inline power monitor.

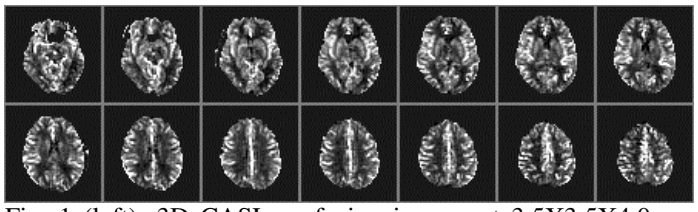
Following each ASL preparation period (labeling duration 3 s, post-labeling delay 1.4 s), a complete 3D data set was acquired in 326 ms using a series (16) of slab selective RF pulses (30^o) with an inter-pulse separation of 20.4 ms. Each low flip angle RF pulse was followed by a complete 2D (xy) EPI readout (TE =8.9 ms) which was phase encoded along the z-axis in centric order. Signal dephasing gradients were applied after each EPI readout. Data were reconstructed to a 64X64X16 3D matrix using parallel imaging ASSET acceleration factor of 2 along the y-axis. The fields-of-view were selected to produce 3.5 X 3.5 mm^2 in-plane resolution and 4 mm slice thickness. Arterial spin labeled and control 3D volumes were acquired alternatively by, respectively, turning on and off RF to the labeling coil. Thirty two pairs of control and labeled image volumes were acquired in 5 min 15 sec.

CASL images were also obtained using 2D multi-slice EPI with similar imaging parameters as used for 3D CASL.

Pixelwise temporal SNR of raw control images, spatial SNR of 5 minute average perfusion ΔS (control-label) images, and fractional signal change due to labeling were measured using a large cortical ROI in the central slice for all subjects.

Results

Temporal SNR of 3D and 2D CASL control images was 208 +/− 32 and 234 +/− 42 (N=6 subjects), respectively. High quality perfusion images were obtained with 3D CASL with all subjects (Fig. 1). The spatial SNR of the average ΔS images was ~20, and 3D CASL was ~10% less on the average than 2D CASL. The ratio of signal change due to labeling between 3D and 2D CASL was 1.05. Figure 2 shows 3D CASL data acquired with the labeling RF offset set to the negative of that used for Fig. 1. Lack of signal in Fig. 2 indicates that the perfusion signal in Fig. 1 is not contaminated by magnetization transfer effects.



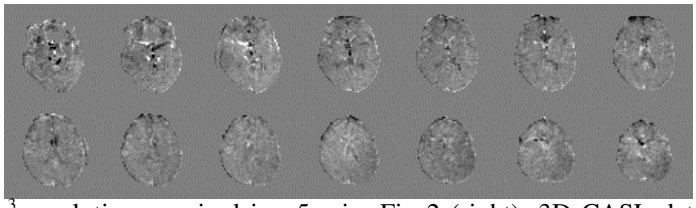


Fig. 1 (left): 3D CASL perfusion images at 3.5X3.5X4.0 mm^3 resolution acquired in ~5 min. Fig 2 (right): 3D CASL data acquired by setting the labeling RF offset to a negative value. Note that the image display level has been set to zero for these images.

Discussion

This study indicates that 3D CASL images with good sensitivity can be acquired using a low flip angle EPI readout train with out segmenting the acquisition over multiple ASL preparation periods. Results show that 3D CASL compares favorably with multi-slice 2D acquisitions. Thus, non-segmented, low flip angle series 3D CASL should allow fMRI studies without any sensitivity penalty and may be better suited for high field studies. However, 3D EPI images suffer from blurring along the z-dimension due to signal weighting in k_z. This can be reduced by using smaller flip angles at the expense of some SNR. Increased number of slices can be achieved with combined application of partial k-space reconstruction and higher parallel imaging acceleration factors.

References

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