3D Spiral In/Out Arterial Spin-Labeled Perfusion Measurement

J. M. Ollinger[1], and A. L. Alexander[2]

[1]Waisman Center, T-231, University of Wisconsin, Madison, Wisconsin, United States, [2]Waisman Center, University of Wisconsin, Madison, WI, United States

Introduction There are two inescapable facts about Arterial Spin-labeled (ASL) perfusion: SNR is an issue and images must be acquired at an optimum uptake time after the tag. Multi-slice ASL is problematic because the uptake interval varies across slices and because background suppression pulses cannot be used to enhance the SNR by nulling the static signal over the entire volume being imaged. It has been demonstrated that 3D GRASE [1] overcomes of these problems. We show here that a 3D sequence using stacked spirals rather than rectilinear phase encoding obtains the same advantages.

Method The sequence is similar to that proposed by Lai and Glover [2] in that it adds axial phase encoding pulses to a multi-echo spiral sequence. Sampling efficiency is maximized by acquiring 2 k-space partitions per echo: one with a spiral-in trajectory and the other with a spiral-out trajectory. The signal from flowing spins is spoiled using diffusion weighting pulses on each axis with b=2 s/cm^2. The x and y diffusion gradients are chosen to compensate for the Maxwell fields induced by the readout gradients. A 64x64 k-space partition is sampled in 20.5 ms with a single interleave. This results in a TE of 52ms and a total imaging time of 400 ms for a 64x64x16 volume. If two interleaves are used the minimum TE falls to 34 ms and a 64x64x32 volume can be acquired in 413 ms per interleave. Alternate interleaves are acquired on inward and outward spirals, so k-space would fully represented by each shot if axial k-space were fully sampled. Reduced axial k-space sampling was used: 22/32 partitions were acquired. Systematic phase errors across partitions and between spiral-in and spiral-out trajectories were corrected with reference data acquired without axial phase encoding. Images were reconstructed using a homodyne reconstruction axially. The bandwidth was 62.5 kHz, the FOV was 22.4 cm, the slice thickness was 3.5mm and the axial FOV was 11.2 cm. There was no slice oversampling. Images were reconstructed to a 128x128x64 matrix size. The images presented here were acquired with 2 interleaves.

Data were acquired on a 3T GE Signa scanner with an 8-channel coil. Perfusion images were generated using the PICORE pulsed ASL method with the QUIPSSII modification [3]. The tag, presaturation, image saturation and QUIPSSII pulses used the BASSI [4] bandwidth modulated pulse for sharp slab delineation. The tag thickness was 10cm with a gap of 1cm. Hyperbolic secant background suppression pulses were applied 532 and 1301 ms after the tag. The QUIPPSS II pulse occurred at TI1=700ms after the tag. Images were acquired at TI=1600 ms. The TR was 2.1 seconds. 52 volumes were acquired: the first was used to model the proton-density, the second as a reference frame, and remainder were averaged using surround subtraction to yield the perfusion image. Perfusion was quantified using the expression [5]

$$f = \frac{\Delta M}{2M_0 TI1} e^{(TI+TE)/T_{1B}}$$

where T1B=1600ms was used for the T1 of blood and M0 was approximated at each voxel by its value in the first volume acquired. This approach has two advantages: T2 relaxation in the "proton density" and perfusion images cancel as do RF inhomogeneity effects. Images were smoothed with a 5 mm Gaussian filter during reconstruction. The signal fluctuation to noise ratio was computed as the ratio of the mean over the perfusion image to their standard deviation. Scan time was 3.57 minutes.

Results Axial and sagittal images of structural and perfusion images are shown in Figure 1. Bright pixels at the periphery are in the CSF and result from taking the ratio of two small numbers. The apparent T2 weighting in the structural images appears in Equation [1] as a ratio so the T2 effects cancel in the perfusion calculation. The SFNR averaged 8.5 over the entire brain yielding an perfusion SFNR of 42.6 for the final image. Smoothing with a 5mm Gaussian increased these figures to 15.2 and 76.

Discussion These results suggest that the 3D spiral sequence has sufficient coverage and SNR to be useful in ASL imaging. The spiral in/out encoding has the advantage of efficiently utilizing the imaging time but at the expense of decreased flexibility in the phase encode ordering. Images acquired with one and two interleaves showed no significant differences other than resolution, suggesting that the sequence is robust with respect to fluctuations in the perfusion signal.

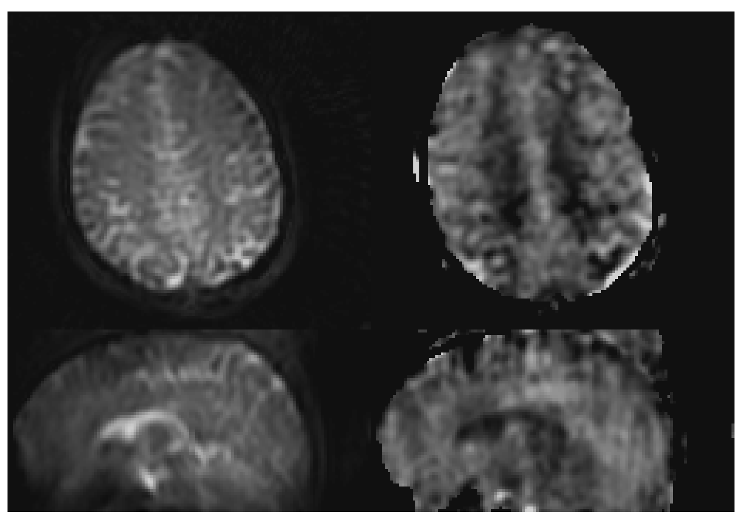

Figure 1. Structural images (left) and perfusion images (right).

References 1.Gunther et al. MRM**,** 54:491–498 (2005) ; 2. Lai et al., MRM 39 :68-78 1998 ; 3. Wong et al., MRM 39 :702-708 1998 ; 4. Warnking et al., MRM 52 :1190-1199 5. Buxton, "Introduction to Functional Magnetic Resonance Imaging."

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