Improved Temporal Resolution in Time-Series ASL Perfusion Imaging with Single-shot 3D GRASE using variable Shared Control Phases

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Objective:

Arterial spin labeling (ASL) technique for cerebral blood perfusion and for functional MRI studies has been limited by long acquisition times. Recent advances in pulse sequence design, higher magnetic field strength and phased array RF coils have substantially improved image SNR to allow the use of fewer signal averages (Navg). The single-shot 3D GRASE has approximately 2.5 times higher SNR than 2D EPI and has slice coverage sufficient to image the entire brain. ASL images are obtained by subtracting (Label-Control) where label phase has both inflowing blood and static brain signal and control phase has primarily background signal from static brain tissue. In theory, control phase data should be invariant in the repeated acquisitions unless bulk head motion or hardware sources of signal drift effect the brain position and signal. To date, time-series ASL imaging uses alternating acquisitions of label phase and control phase data. Our objective in this work is to develop an efficient technique for time-series (cine) ASL perfusion imaging of the brain by combining single-shot 3D GRASE with a modification of the signal acquisition scheme to share periodically acquired control phase data.

Methods:

Our labeling scheme used pulsed ASL technique in single shot 3D GRASE (1) with background suppression inversion pulses and QUIPSII modified for outer volume suppression to minimize aliasing of outer slab regions. Experiments were performed on 1.5T (Siemens, Sonata) and 4T (Bruker) using an 8-channel head array coil. Both systems had identical 40mT/m maximum gradient systems and identical sequence control software which allowed porting of sequences between the scanners. The sequence had parameters: inflow time TI (1500ms), TR/3.5sec, bandwidth/2790 hz/pixel, FOV 200x400mm, 31x64x14 acquired data matrix, half Fourier, 26 sections and voxel size 6.4x6.3x3.5 mm^3 at 1.5T and 6.4x6.3x2.5 mm^3 at 4T. The time-series sequence was modified in the ICE program to obtain an adjustable number label data following each of a variable number of control data. All data is acquired at a constant TR interval. Several phantom studies using static doped water phantom were used to identify signal changes. Four normal volunteers between the age of 25 and 50 were imaged. The time-series obtained in one subject used 3 label phases per control phase, C_N / L_M [3/3] to produce 9 ASL 3D perfusion maps at 4T with Navg/1. In the same subject at 1.5T using Navg/2 and C_N / L_M [3/10] and otherwise identical parameters produced 30 label phase measurements and corresponding ASL 3D perfusion image sets. The mean signal intensity and associated SNR was measured in a region covering the entire brain section which averaged the signal in white matter and grey matter. Intensity in air was used for noise.

Fig. 1

Results Figure 2 shows one of the 26 sections covering the entire brain acquired at 4T (top row) and 1.5T (bottom row) with C_N / L_M and mean signal intensity (M) shown below each image. The mean of the average signal *intensity* in the 9 phases at 4T is mean/SD (μ, σ) 328/11.7 and at 1.5T in 30 phases the mean/SD is 63.7/4.0. Similarly for the respective average *SNR* at 4T is mean/SD (14.3/1.2) and at 1.5T (8.52/ 1.2). Calculated in a single image of Fig.2, the SNR in the left parietal cortical gray matter at 4T is 667/28 = 23.8 and at 1.5T is 117/11.7 = 10.

Discussion There was no noticeable visible difference in brain perfusion in the time-series images. The variance in the mean intensity may be due to physiologic changes during the imaging study as a function of variable heart rate, inflow time and brain activity. At 4T the image sensitivity in the 3D FT approach was sufficient without signal averaging to obtain whole brain perfusion with 26 images using one acquisition of labeled data. For fMRI, the shared control ASL technique might be applied with other readout sequences where if CPMG refocusing and background suppression is not used, care would be required to minimize BOLD effects in the control data. The timing of the control phases could also be made compatible with timing in single trial paradigms. Time series ASL may be useful for drug therapy studies, monitoring tissue perfusion during therapeutic treatment of stroke and potentially for real time monitoring in image guided tumor therapy.

Conclusion The shared control technique demonstrate extreme speed-up of ASL time-series imaging of the brain, at no SNR penalty by eliminating redundant control data.

References 1. Günther M, Oshio K, Feinberg DA: *Magn Reson Med* 54, 491-8, (2005)

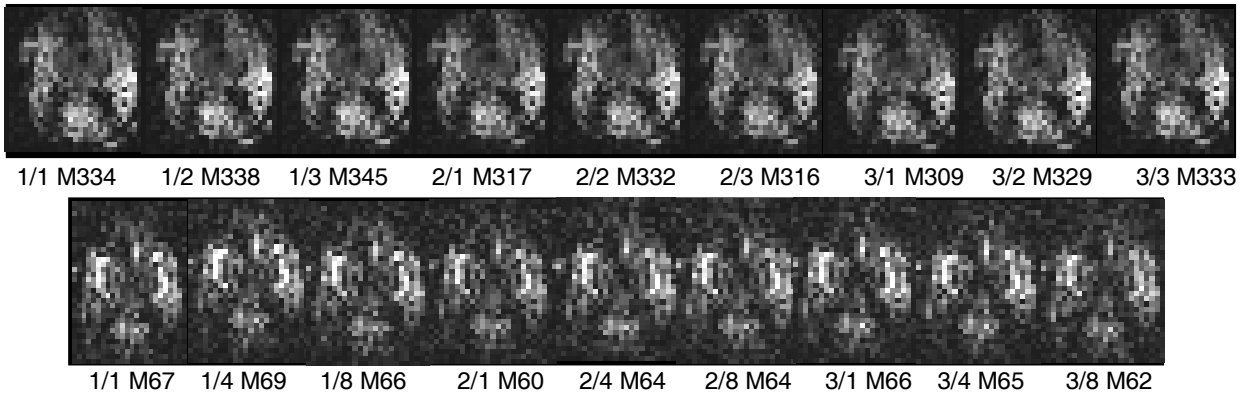

Fig.2 ASL time-series (top) 4T, Navg/1, (bottom) 1.5T, Navg/2, with C_N / L_M , M mean signal, see text.