Vessel Encoded Arterial Spin Labeling using Pseudo-Continuous Tagging

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Introduction

In pseudo-continuous ASL (1), a long train of discrete RF pulses is used to effect a flow driven adiabatic inversion. We describe here a modification of this tagging scheme that allows for efficient encoding of vessels within the tagging plane, such that two or more vascular territories can be imaged simultaneously with the same SNR as a conventional ASL scan with the same scan time.

Methods

Three modifications are required to allow for encoding of vessels within the inversion plane: 1) the use of a single labeling gradient waveform with non-zero mean for both tag and control conditions; 2) the application of additional gradients perpendicular to the labeling gradient to generate phase shifts between the vessels of interest; and 3) the use of RF phase cycling to place the desired vessels in tag and control conditions and encode them according to a Hadamard or similar encoding schedule. For two vessels, a 4 cycle Hadamard encoding schedule is shown in **Table 1**, and the tagging pulses for this scheme are shown in **Figure 1**. The direction and area of the dashed gradient pulses labeled G[xy] are tuned to produce a phase shift of π between the two vessels, allowing for one vessel to experience a coherent pulse train (inversion tag) and the other a train of alternating phase (transparent control). For sufficiently short inter-pulse spacing, this tagging scheme results in calculated tagging efficiencies of ≥90%for flow velocities of 10-40cm/s. By inverting the sign of every other RF pulse, vessels can be switched from tag to control conditions and vice versa.

Scanning and tagging parameters were: GE 3T scanner; transmit/receive birdcage coil; tagging RF pulses of 600μs duration, 960μs spacing, Hanning widow shaped with an amplitude of 0.04G; slice selective gradient of 0.6G/m amplitude during the RF pulses, with a mean gradient of 0.08G/cm; FOV 24cmx8mm; single shot spiral readout. The length of the tagging pulse train was limited to a suboptimal 800ms by software constraints. The post labeling delay was 1200ms and TR was 2500ms. 30 images were acquired of each of the 4 cycles for a total scan time of 5min. Mean and RMS B_1 were 0.014G and 0.020G, respectively, which corresponds to an SAR of less than 2W/Kg (2) in the head during the tagging pulse train, and 1W/Kg for a typical tagging duty cycle of 50%.

Table 1: M_z for Four Cycle tagging scheme

Cycle	Ves. 1	Ves 2
1	1	1
2	-1	-1
3	1	-1
4	-1	1

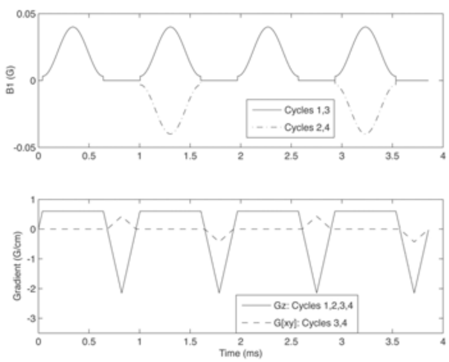

Figure 1: RF and gradient waveforms

Results

Vessel encoded images are shown in **Figure 2**. In the left panel, left and right carotids are encoded, and in the right panel, the carotids are separated from the vertebral arteries. The total CBF, difference signal between vessels, and the individual vascular territories can be reconstructed from the encoded data.

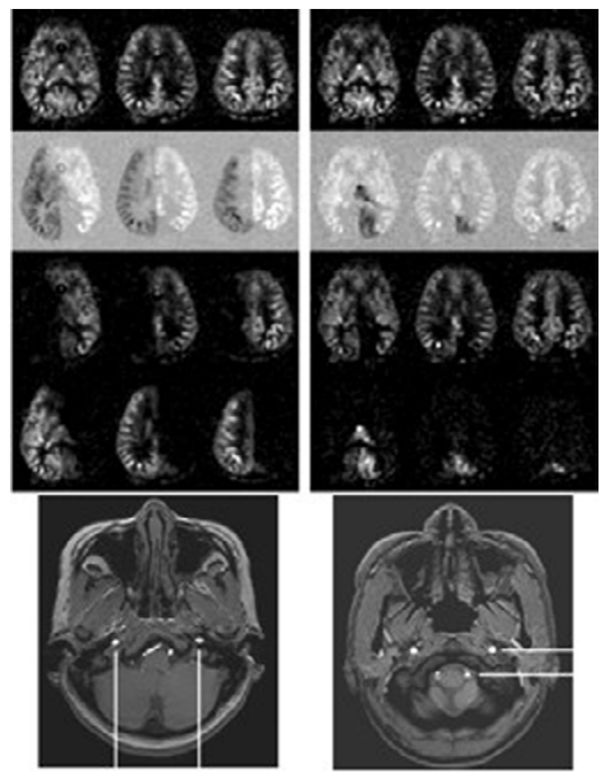

Figure 2: Two vessel encoding. Bottom row shows tagging plane and location of tag and control bands. Referring to the cycling scheme in Table 1, rows (from top) are: (1-2); (3-4) ; (1-2+3-4); (1-2-3+4).

Discussion

The vessel encoded ASL method described here provides simultaneous perfusion images of two or more vascular territories, with the same SNR as conventional ASL images. This follows from the fact that each vessel is fully tagged or fully relaxed prior to every image acquisition, with equal numbers of tag and control states, and all data is used for the reconstruction of each vascular territory. These conditions can be met whenever the tagging schedule for each vessel follows a tagging cycle that is a column from a Hadamard matrix other than the column containing all 1s. For N vessels, the time savings relative to sequential vascular territory imaging (3,4) of individual territories is a factor of N.

Acknowledgements

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References

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