Rapid Imaging of Multiple Vascular Territories using Cycled Arterial Spin Labeling with Independent Component Analysis

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Introduction: Recently, a regional arterial spin labeling (regASL) approach was presented (1,2) which separates the vascular territories of the anterior and posterior circulation by acquiring the perfusion images using different positions of labelling slabs. By performing the labeling in each feeding artery as a separate acquisition experiment, regASL increases the total imaging time by two or more according to the number of regions imaged. Another problem is the labelling slabs must be positioned precisely on the feeding artery to assure exclusive labeling the targeted feeding vessel. Utilizing an MRA data set can lead to mis-registration of the labeling slab and partial volume labeling of incorrect vessels if there is even small movement between the acquisitions of the MRA scout and regASL data sets. Here, we present a technique that has no time penalty or SNR loss compared to ASL without regional definition by encoding several different combinations of vascular territories in different cycles within a single experiment instead of acquiring signal averages. In addition to the improved time efficiency, the cycled ASL allows the application of independent component analysis to largely overcome the above problems due to imprecise slab labeling positioning.

Materials and Methods: The ASL experiment can be viewed as kind of a gradient cycling experiment, where the sign of the longitudinal spin magnetization of the inflowing blood changes. In this abstract, the ASL experiment will consist of 4 different phases (instead of two in conventional ASL) with each phase determined by a unique inversion slab covering different combinations of feeding vessels (Fig.1). To separate the vascular territories of the three regions (left and right internal carotid artery (ICA) and basilar artery) the resulting four data sets are combined according to the number (+1 or -1) in the corresponding row of the table in Fig.1. Reliable saturation of the imaging slab after labeling was achieved by a WET pulse as described in (2).

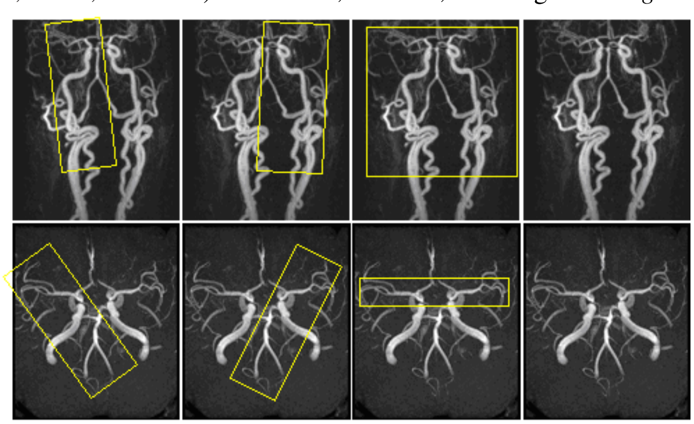
All measurements were performed on a clinical 1.5T MR-Scanner (Siemens Sonata, 40mT/m, 200µs). Ten human subjects were examined using a single-shot 3D-GRASE readout technique (3) with the following parameters: inflow time 1500ms, echo time 36ms, repetition time 2500ms, 26 interpolated partitions, 12 repetitions (total acquisition time: 2 min). An almost isotropic resolution of $4.7\times4.7\times4.5$ mm^3 was achieved.

After data acquisition an independent component analysis was performed in a 4-dimensional space spanned by the four phase of cycled ASL. Note all data is used to calculate each regional ASL image to maximize SNR. All 26 slices were incorporated without masking. Intensity images of all three vascular regions were combined into a single image by using three independent color channels (right ICA territory in red, left ICA territory in green, and basilar artery territory in blue) as shown in Fig.2.

Results and Discussion: Colored rCBF maps demonstrated the cortical vascular perfusion pattern providing a sharp delineation of anterior and posterior vascular territories in 7 subjects. Independent component analysis provided identical results. In 3 out of 10 subjects separation of vascular territories was incomplete, (Fig.2, top row) seen as low intensity signal and altered color. After independent component analysis separation was improved markedly in all subjects. The overall SNR measurements were 11.1 +/- 4.1 and 19.3+/- 4.7 for conventional ASL and cycled regional ASL, respectively, thus showing the increased SNR within the same acquisition time.

Conclusions: The goal of our work was to develop a technique to acquire at least three vascular territories (left and right ICA and basilar artery) in two minutes. The proposed technique adds this information at no SNR or time penalty by replacing the conventional inefficient signal averaging of standard ASL methods with cycled encoding for different linear combinations using all of the cycled data to achieve the same noise reduction. Performing independent component analysis yields better separation of vascular territories for improved reliability and robustness of the technique. These steps to provide improved separation in reduced scan time enable the incorporation of regional brain perfusion imaging into routine clinical protocols.

References: 1.) Hendrikse J, van der Grond J, Lu H, et al: *Stroke* **35**, 882-7, 2004. 2.) Golay X, Petersen ET, Hui F: *Magn Reson Med* **53**, 15-21, 2005. 3.) Günther M, Oshio K, Feinberg DA: *Magn Reson Med* **54**, 491-8, 2005.



	label phase 1	label phase 2	label phase 3	label phase 4
right ICA	-1	1	-1	1
left ICA	1	-1	-1	1
basilar	-1	-1	1	1

Fig.1 Position and orientation of labeling slabs for cycled ASL. Labeling is performed by always covering two vessels in varying combinations at a time.

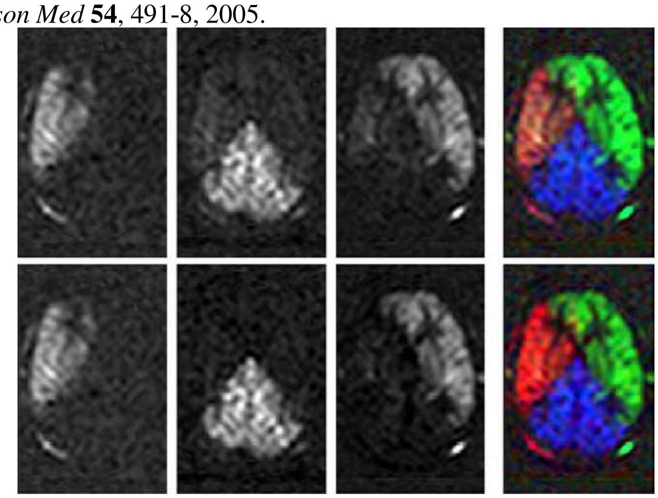


Fig.2 One out of 26 segments acquired in 2 min. Top row shows the vascular territories calculated as given in table of Fig.1. Vascular territories cannot be separated completely due to improper labeling slab position. Bottom row shows the improved separation after independent component analysis.