An Efficient Labeling Scheme for CASL for use with Multiple, Independently Switched Coils

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Introduction: Arterial Spin Labeling (ASL) is a non-contrast based method for assessing quantitative cerebral blood flow and cerebral perfusion. It is an alternative to contrast-based imaging techniques when the use of contrast agents is not desired as for example in a pediatric population or if the use of contrast agents poses a danger to the patient. It was shown in the past that continuous ASL (CASL) is able to visualize vascular territories by placing small labeling coils directly over the right (RC) and left (LC) carotid as well as the vertebral arteries. Recent studies also showed that it is possible for pulsed ASL (PASL) to achive selective tagging by employing 2-dimensional labeling slabs [1-3]. A recent publication presents a scheme to increase the tagging efficiency of PASL with selective excitation [4]. Here we present a scheme for efficient CASL tagging that allows independent calculation of the signal from the individual coils. This scheme was implemented for and tested with a 3-coil CASL apparatus.

Methods: Each coil in a multi-coil CASL apparatus can have one of two states during a labeling experiment, label (on, L) or control (off, C). A binary system with n elements has 2^n different states. In the case with 3 label coils, 8 states are possible as shown in figure 1.

If an experiment is performed with a paradigm length of 8 where the different states are played out, an addition and subtraction scheme as shown in the center row of figure 1 ensures that only the signal from one coil adds constructively while the signals from the other coils get subtracted out.

We implemented our technique on a 3.0T MR scanner (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany). A clinical EPI sequence was modified to output control signals on three user accessible output channels (Osc0, Osc1, ExtTrigger). These three channels were assigned to three individual small loop label coils. Two were placed on the neck to cover the RC and LC, respectively, the third coil was placed in the back covering the vertebral arteries. The user can adjust the paradigm pattern and length, as well as the duration of the labeling pulse and delay time after the labeling pulse with the scanner interface. The control signal is switched to high for the duration of the labeling pulse and is sent to a custom-built RF cabinet that can switch the three coils independently during the acquisition. If the control signal from the scanner is received for a given coil, this coil sends an RF pulse of the required frequency and duration. All local coils are individually detuned when they are not transmitting and have active and passive detuning circuitry built in to prevent coupling with the body coil. Maximum RF amplitudes and pulse durations were limited so that the total RF deposition stayed within the SAR limits mandated by the FDA.

Measurements were performed on healthy volunteers in accordance with local ethics committee regulations.

Single-shot gradient echo EPI images were acquired. The sequence parameters were as follows: TE=28ms, TR=4.8s, matrix=64x64, label time=2.7s, post-label delay=700ms. 17 slices with a thickness of 5mm and 1mm gap were acquired. The paradigm of length 8 from Fig. 1 was repeated 10 times for a total of 80 measurements, resulting in a measurement time of 6:24min.

Results and Discussion: Figure 2 depicts the three reconstructed signals encoded as color channels. Red corresponds to the labeling scheme for the RC, green to the labeling scheme for the LC and blue to the labeling scheme for the vertebral arteries. Red signal dominates the right hemisphere and green signal the left hemisphere, as expected. Blue signal can be mainly seen in the lower back of the head, but not as strong as expected in the cerebellum. This may be due to the fact that in this particular experiment the label coil in the back was inadvertently shifted, which could have led to suboptimal label efficiency.

Conclusion: An effective labeling scheme for multi coil CASL that allows the visualization of vascular territories is described. The labeling scheme can be used with any number of coils, the paradigm length scales with $2^{\#coils}$. Perfusion maps from each single coil utilize all acquired measurements, yielding the highest possible efficiency. The labeling scheme could also be used for territorial mapping with PASL. The method was implemented for use with three or less label coils and was successfully tested on volunteers.

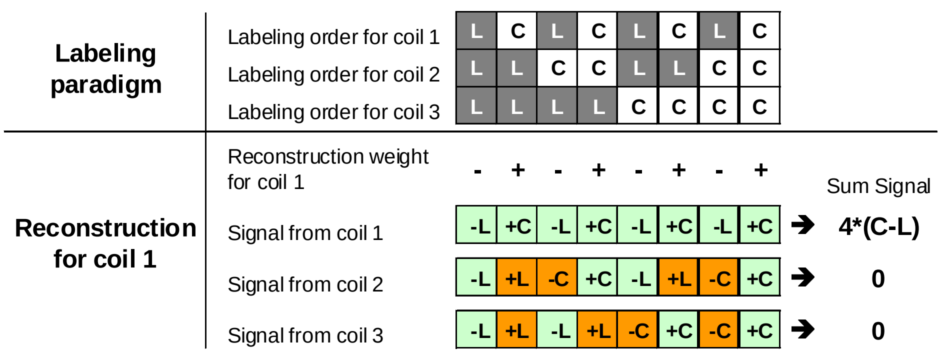

Fig 1: A schematic labeling paradigm for the individual coils is shown on top, L indicates labeling and C denotes control. On bottom the reconstruction scheme for coil 1 is shown (reconstruction for coil 2 and 3 is performed with corresponding weight functions). The signal contributions from the individual coils are shown below. Green boxes indicate signals that contribute 'correctly', i.e. Label images that are subtracted and Control images that are added, orange boxes indicate the opposite cases. Paired green and orange label or control contributions from single coils cancel each other, leading to zero signal contribution from the respective coil. (The actual implementation for the paradigm has the columns permuted with respect to the schematic to be less prone to patient motion.)

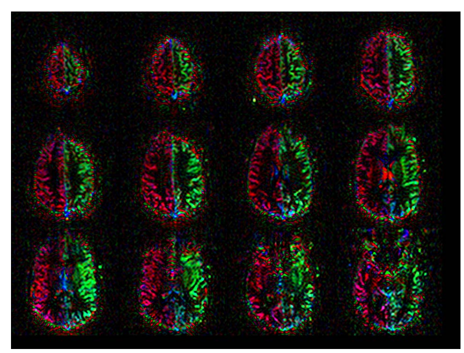

Fig 2: Composite image of the three individually reconstructed perfusion maps. Red color indicates signal labeled with the coil on the right carotid artery, green signal labeled with the coil on the left carotid artery and blue indicates signal labeled with the coil underneath the vertebral arteries.

References: [1] Eastwood JD et al. (2002) MRI 20:583:586. [2] Davies NP et al. (2003) MRM 49:1133-1142. [3] Golay x et al. (2004) MRM 53:15-21. [4] Guenther M. (2006) MRM 56:671-675.

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