Arterial Spin Labeling Measurement of Arterial Perfusion Territories Using a Localized Labeling RF Coil

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INTRODUCTION

Arterial spin labeling (ASL) techniques have proven to be an excellent tool to obtain quantitative maps of perfusion non-invasively [1, 2]. ASL is gaining wide-spread use in clinical applications where, together with other MRI techniques such as angiography (MRA), diffusion-weighted MRI (DWI) and T_2-weighted MRI, it has proven useful for the diagnosis of a variety of cerebrovascular diseases [3]. Recently, there has been increased interest in using ASL techniques to map vascular territories of major cerebral arteries [4-8]. Vascular territory maps can provide complimentary information to MRAs in identifying the source of vascular occlusions and in predicting and verifying the extent of the affected area. They can also pin-point anomalies and defects of the Circle of Willis, when perfusion and transit-times of the two brain hemispheres become asymmetric and the patient presents high risk of infarction. In the present study, a three coil system comprised of a small figure-8 shaped labeling coil, a homogeneous volume excitation coil and a receive-only quadrature surface coil was employed to selectively obtain perfusion territory maps of the major feeding arteries to the brain. Vessel selectivity was achieved by utilizing oblique labeling planes while exploring the limited spatial coverage of the labeling coil.

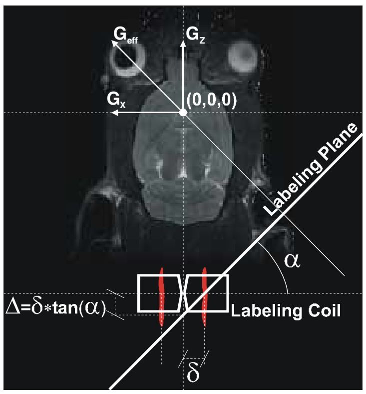

Figure 1: Diagram of the labeling scheme used to label blood flowing in just one of the carotid arteries.

MATERIALS AND METHODS

Sprague-Dawley rats (200-350g), orally intubated and maintained anesthetized under isoflurane, were scanned in a horizontal 7T/30cm magnet (Bruker-Biospin, Billerica, MA) equipped with gradients capable of 300 mT/m amplitude (Resonance Research Inc, Billerica, MA). A home-built, transmit-only birdcage volume RF coil, 12 cm internal diameter, and a commercially-built, receive-only quadrature surface coil (RAPID Biomedical GmbH, Rimpar, Germany), were used for all image acquisition. A small figure-8 shaped labeling coil [9] was positioned under the neck of the animal, approximately 2 cm away from isocenter. All coils were equipped with active decoupling circuits to minimize coil-to-coil interferences during the labeling and imaging phases of the experiment, and to avoid off-resonance saturation of water in the acquisition region [9]. Continuous arterial spin labeling (CASL) was obtained with adiabatic flow-driven inversion of the chosen feeding arteries. Figure 1 illustrates the concept used to obtain selective labeling of individual arteries. A labeling plane was defined by rotating the labeling gradient G_{eff} in the horizontal plane by an angle α with respect to the longitudinal axis. Because of the confined excitation profile of the labeling coil, only the arteries passing over the intersection of the labeling plane with the labeling coil undergo the ASL inversion. Thus, when $\alpha = 0$, both left and right common carotid arteries (CCAs), as well as both left and right vertebral arteries (VAs) are labeled. When $\alpha \geq 45º$, only the right CCA is labeled, and when $\alpha \leq -45º$, only the left CCA is labeled. Even though the use of a separate labeling coil minimizes magnetization transfer effects [9], the control images were acquired using a gradient rotated by an angle $-\alpha$ with respect to the longitudinal axis.

RESULTS AND DISCUSSION

Figure 2 shows perfusion-weighted images (control-labeled) for selected horizontal and coronal slices using $\alpha = \pm 60º$. The second and third rows show perfusion of the left and right hemispheres, due to labeling of only the left and the right CCA, respectively. A bright line can be seen in the horizontal perfusion images and corresponds to the oblique labeling plane. A coronal perfusion slice (third row, third column) shows bright muscle signal due to the intersection of the labeling plane with that slice. By setting $\alpha = \pm 60º$, the VA and the basilar artery (BA) are not labeled, and thus no cerebellar perfusion contrast is obtained. An interesting asymmetry in the cingulate cortex corresponding to the territory of the anterior cerebral artery (ACA) can be observed. Perfusion of both sides of the cingulate cortex is accomplished by labeling the right CCA, but not the left. The forth row in Fig. 2 shows whole brain perfusion afforded by setting $\alpha = 0º$ in the labeling scheme described above, so that both CCAs and VAs are labeled, when cerebellar perfusion is obtained.

Perfusion-weighted images using $\alpha = \pm 45º$ are depicted in Figure 3. Artifacts outside the brain corresponding to the labeling plane achieved when $\alpha = -45º$ (left) or when $\alpha = 45º$ (right) can be seen in the difference images (bottom row). Unlike the case when $\alpha = \pm 60º$ shown in Fig. 2, the lower angle of the labeling plane allowed labeling of both VAs, so that perfusion of the entire cerebellum is observed. Therefore, adjustments of the angle of the labeling plane allows for varied selectivity and the combination of small and large angles may be useful to determine the vascular territories of arteries that are not easily accessible with the described method.

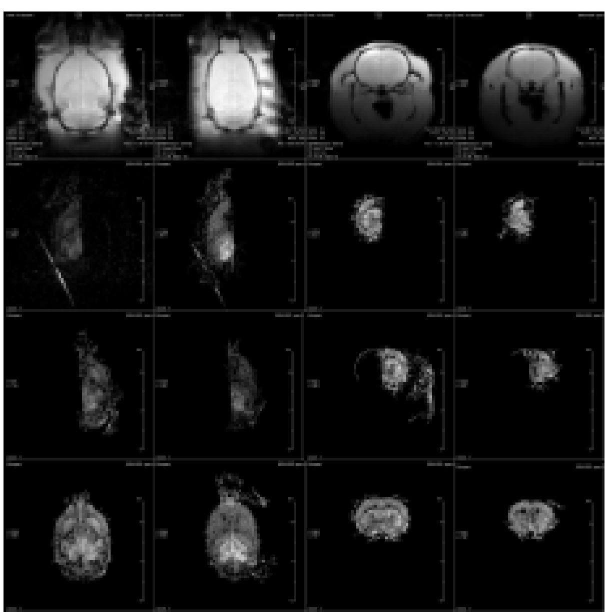

Figure 2: Anatomical control images for selected horizontal and coronal slices (1st row). Perfusion-weighted images using $\alpha = -60º$ (2nd row), $\alpha = +60º$ (3rd row) and $\alpha = 0º$ (4th row).

CONCLUSIONS

The combination of a separate labeling coil with proper placement and direction of the labeling plane allows for demarcation of the perfusion territory of major cerebral feeding arteries with reduced magnetization transfer effects and high SNR. The method described allows use of different angles of labeling to evaluate different perfusion territories including those from arteries that are not uniquely accessible, a useful feature for the diagnosis of cerebrovascular diseases.

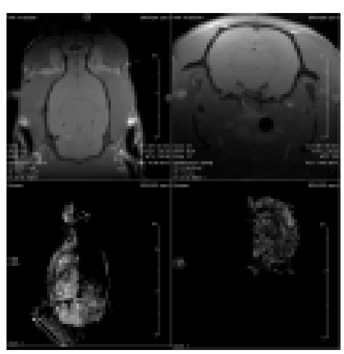

Figure 3: Perfusion-weighted images using $\alpha = -45º$ (left) and $\alpha = +45º$ (right).

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