Continuous Artery-Selective Spin Labeling (CASSL) applied to distal branches of intracranial arteries

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Introduction

Several methods in perfusion imaging are able to image perfusion territories of cerebral arteries [1]. Most of them only allow for labeling of extracranial arteries like left- and right-sided carotids or vertebral arteries. However, a clear delineation of the border between smaller territories is not possible and often impedes a reliable diagnosis, e.g. the distinct allocation of the origin of an embolus.

Continuous Artery-Selective Spin Labeling (CASSL) [2] is one technique to image perfusion territories of cerebral arteries. So far, CASSL was only applied to major brain feeding arteries. In this study we optimize key labeling parameters and demonstrate the feasibility of this method to selectively label blood of individual branching intracranial arteries even in the immediate vicinity of other small vessels in-vivo. In stroke patients, especially in patients with embolic stroke the resulting perfusion maps provide important information for therapeutic decisions. Furthermore, this can help to understand the functional significance of vasculopathies in general.

Material and Methods

In CASSL an oscillating motion of the labeling gradient about the axis of the artery combined with frequency modulation allows labeling of the desired artery. A saturation of the magnetization in non-selected vessels depends basically on the angle θ between selected vessel and rotating labeling gradient, its rotation frequency f_{rot} and the distance d from the labeling focus, respectively. By increasing the angle θ, the labeling focus can be made more selective. The overall effect of the CASSL pulses above a certain distance of the selection point is to cause a saturation of the magnetization. The ratio of the maximum velocity of the labeling plane v_{max} and the velocity of the blood flow v_{blood} determines how many times the blood will move through the labeling plane and therefore how often the blood's magnetization experience a certain change in orientation. The maximum velocity of the rotating labeling plane is given by

$$v_{max} = 2\pi f_{rot} d \tan\theta \quad [2] .$$

Labeling parameters are chosen for $v_{max}/v_{blood} \geq 3\pi/2$ so that blood with $v_{blood} \leq 40$ cm/s flows through the labeling plane at least three times.

We investigated the selectivity by shifting the location of the labeling focus in the right left direction at the internal carotids of five volunteers for different angles θ. The focus position was changed over a distance of 20 mm starting from the middle of the targeted vessel. On the basis of these results, labeling was applied in eight more volunteers to small arteries with diameters of 3 mm and less that are branching from media and anterior cerebral artery, mainly to A2/A3 and M2/M3 segments, respectively.

MR images were acquired with a standard transmit/receive head coil on a clinical 1.5 T Philips Intera MR system. For planning of the labeling position, a 2D inflow angiography was performed. Labeling parameters were as follows: Labeling duration 2.2s; post labeling dealy 0.8 s. Further parameters were chosen according to a previous study with a fixed labeling plane [3]. Scanning parameters were: FFE-EPI acquisition; FOV 220x176 mm; scan matrix 80x71; TR/TE, 3475/26 ms; 5 to 7 slices; thickness, 8 mm; gap, 1 mm; 40 labeled and 40 non-labeled acquisitions; scan time 4:51 min; SAR, 2.1 W/kg.

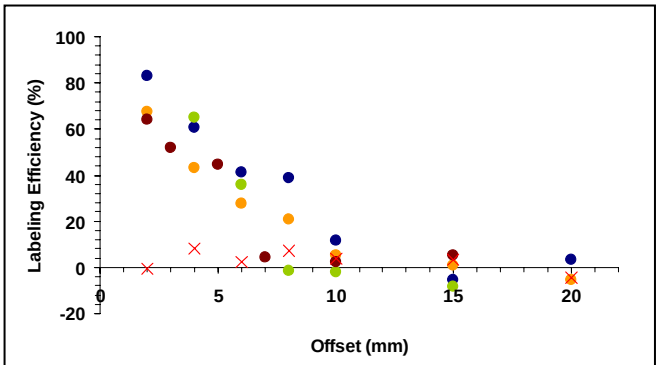

Figure 1: Labeling efficiency (signal intensity of selective versus non-selective ASL) against the offset of the labeling focus for angles of 8°(•), 10°(•), 12°(•) and 15°(•). Crosses (x) indicate the signal of the non-selected ICA.

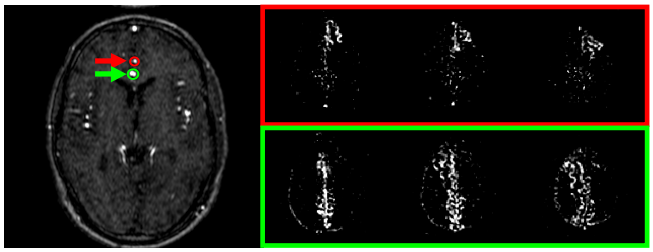

Figure 2: Labeling of A3 segments of the ACA. Vessels of interest are in a distance of 11.9 mm. θ was set to 8°.

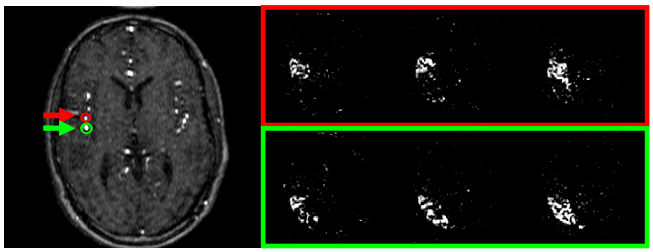

Figure 3: Labeling of M3 segments of the MCA. Vessels of interest are in a distance of 9.5 mm. θ was set to 10°.

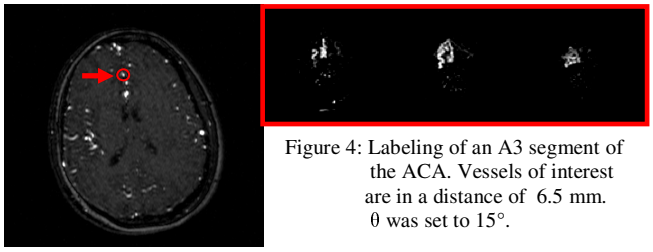

Figure 4: Labeling of an A3 segment of the ACA. Vessels of interest are in a distance of 6.5 mm. θ was set to 15°.

Results and Discussion

Figure 1 shows signal curves for different combinations between the angle θ and the offset of the labeling focus. Excellent information is provided about the selectivity of CASSL. An angle θ=8° ensures a saturation of the magnetization in the non selected artery when the offset exceeds approximately 12 mm. For θ=15° offsets greater than approximately 7 mm will guarantee no labeling in adjacent vessels.

Figure 2 to 4 show well delinieated perfusion territories of A2/A3 and M2/M3 segments for selected arteries in the immediate vicinity of other small vessels. The averaged ASL signal measured in manually drawn ROIs obtained signal intensities of 61% (θ=15°) to 82% (θ=8°) when compared to globally labeled scans at the same labeling position.. A complex vascular architecture may result in an intersection of the labeling plane with part of the imaging volume. This causes artefacts in the perfusion subtraction images. As these do not impinge on the perfusion territory, these artifacts are not important. This makes CASSL a suitable technique to selectively label blood of intracranial arteries in-vivo and shows the method's flexibility for differing geometries. This is especially true wherever an artery of interest is branching from a larger artery and is supplying the tissue at short distance from the branching-point. Perfusion territories of single small intracranial arteries may provide important information about border zones of perfusion and can improve diagnostic processes.

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References

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