

# Pseudo-Continuous Artery-Selective Spin Labeling (pseudo-CASSL)

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## Introduction:

Pseudo-continuous arterial spin labeling (psCASL) is a newly proposed technique, which employs a train of discrete RF pulses that mimics continuous ASL, but has a much lower SAR [1]. A couple of different methods have been proposed that allow for imaging of perfusion territories [2-4]. These adaptations employ additional gradient pulses perpendicular to the axis of the vessel to generate a phase gradient across the labeling plane. These pulses are applied in between the RF pulses. By varying the orientation of these added gradients, a labeling spot can be defined at the targeted artery. However, there is the risk of unwanted labeling distal to the selection point so that other vessels may also be tagged. Although this unwanted labeling can be minimized by changing the amplitude [3] or by using a random ordering of the added gradients [4], the development of a method which would completely avoid this problem would be advantageous. By employing additional gradients during the application of the RF pulses, the influence is made local, circumventing phase effects further away from the targeted vessel. Here we describe a modified tagging scheme employing the idea of continuous artery-selective spin labeling (CASSL) [5] that combines the pseudo-continuous labeling mechanism with a moving labeling plane to achieve selective labeling of a single vessel. This scheme is shown in Figure 1.

## Materials and Methods

The method is based on the gradient scheme of balanced psCASL. Instead of only applying a fixed labeling gradient aligned with the flow direction an additional gradient perpendicular to the labeling direction is added. By changing the orientation of the slice-selective gradient for every RF pulse a stepwise precessionary movement of the labeling plane is achieved. Refocusing gradients were added to avoid unwanted phase accumulations due to the extra gradients. The tilting angle between artery and labeling plane has a constant value  $\theta$  while the labeling plane is rotating with a constant frequency  $f_{rot}$ . This leads to the resonance condition always being fulfilled at the same spatial position for the selected artery, but for any other artery the locus of resonance will vary in time. The overall effect of the CASSL pulses above a certain distance  $d$  from 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 determines how many times the blood will move through the labeling plane of a neighbouring artery and therefore how often the blood magnetization will experience an RF pulse. The maximum velocity of the labeling plane along the neighbouring (unwanted) artery is given by [5] as

$$v_{max} = 2\pi \cdot f_{rot} \cdot d \cdot \tan\theta.$$

By increasing the tilting angle of the labeling plane and by increasing the rotation frequency, respectively, the labeling focus can be made more selective. Scanning and tagging parameters were as follows: Philips 3T Achieva scanner; FOV 220x220mm, voxel size of 2.7x2.7x6 mm, FFE-EPI read-out. Labeling duration 1.65 s, postlabeling delay 1.525 s with background suppression, 15 slices and 10 averages of label and control images. Scan time approximately 1:40 min. We investigated the selectivity by changing the location of the labeling focus for different scans in the right left direction (random order, the focus position was changed over a length of 30 mm starting from the middle of the targeted vessel). This procedure was repeated for different tilting angles and rotation frequencies and we targeted the internal carotids of seven volunteers (2 female, 5 male).

## Results and Discussions

Figure 2 shows the labeling efficiency as a function of the tilting angle of the rotating labeling plane for the selected and for the non-selected carotid artery. Increasing the tilting angle decreases the size of the labeling focus and labeling becomes more selective at the cost of the labeling efficiency. For the selective labeling of a carotid artery (averaged separation of carotids from seven volunteers is 5.5 cm), a tilting angle of 12° seems sufficient. Figure 3 shows the dependency of the labeling plane's rotation frequency on the selectivity of pseudo-CASSL: A higher rotation frequency implies that spins of a non-selected artery flow through the labeling plane multiple times which results in a higher selectivity. Figure 4 shows the labeling efficiency against the offset of the labeling focus for different tilting angles. Greater tilting angles clearly lead to an improved selectivity of the method, e.g. an angle of 20° ensures a saturation of the magnetization in the non-selected artery when the offset exceeds approximately 18 mm. Figure 5 shows the perfusion images of right and left internal carotid artery and of the basilar artery of a normal volunteer (25 averages of label and control images) showing the capabilities of this method to selectively label brain supplying arteries.

## References

- [1] Wu et al, MRM 2007;58:1020-1027; [2] Wong, MRM 2007;58:1086-1091;
- [3] Dai et al, ISMRM 2008, abstract 184; [4] Helle et al, ISMRM 2008, abstract 183
- [5] Werner et al, MRM 2005;53:1006-1012

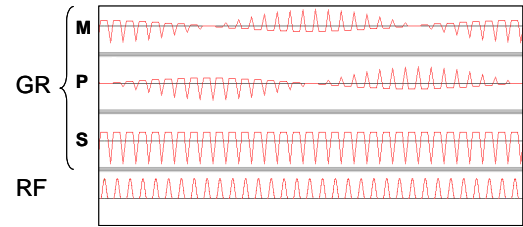


Figure 1: Labeling scheme of pseudo-continuous artery-selective arterial spin labeling (pseudo-CASSL).

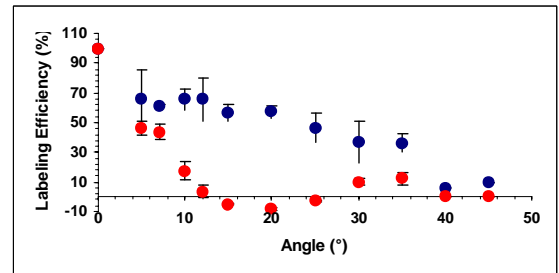


Figure 2: Labeling efficiency (signal intensity of selective versus non-selective ASL) as a function of the varied tilting angles and a rotation frequency of 80Hz for the selected (•) and for the non-selected carotid artery (•).

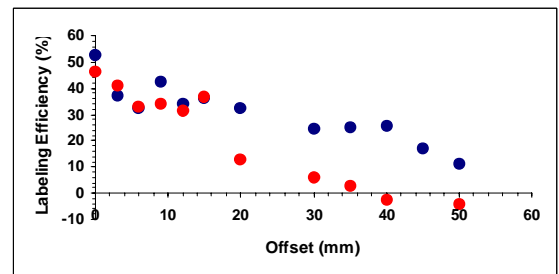


Figure 3: Labeling efficiency against the offset of the labeling focus for a tilting angle of 12° and two different rotation frequencies of 80Hz (•) and 120Hz (•).

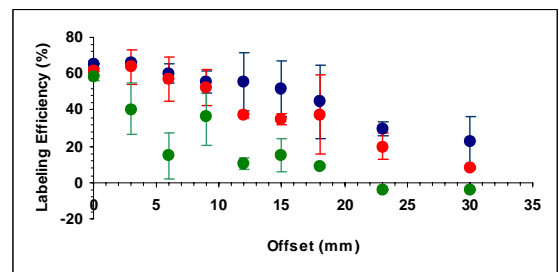


Figure 4: Labeling efficiency against the offset of the labeling focus for tilting angles of 10° (•), 15° (•) and 20° (•) and a rotation frequency of 80Hz.

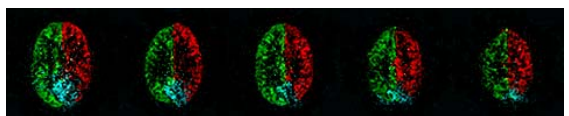


Figure 5: Color encoded perfusion territories of left and right internal carotid arteries (red and green) and basilar artery (blue).