Multi-vessel labeling approach for perfusion territory imaging in pseudo-continuous arterial spin labeling

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INTRODUCTION: A new method named superselective pseudo-continuous arterial spin labeling (superselective ASL) has been recently introduced for perfusion territory imaging [1]. The technique employs a circular labeling spot that can be adjusted in size and thus can be adapted to individual arteries ranging in size from internal carotid arteries (ICA) to small intracranial vessels, even those distal to the Circle of Willis. However, this approach requires seperate measurements for individual arteries. For other selective ASL methodologies different labeling schemes have been proposed in which more than one vessel is labeled and individual flow territories are subsequently recalculated from the acquired data [2,3]. In this study, we propose a new labeling scheme for superselective ASL that utilizes an elliptical labeling spot to label the blood in multiple vessels simultaneously. This makes it possible to recalculate four perfusion territories from the data acquired in three measurements resulting in decreased scan time. Multi-vessel labeling can also be advantageous for the visualization of the posterior flow territory that so far required exclusive labeling of the basilar artery (BA) which bears the risk of undesirable artifacts due to interference between imaging volume and labeling plane. Moreover, an increased labeling spot potentially results in better labeling efficiency which can improve the overall image quality.

MATERIAL and METHODS: Superselective ASL employs additional time-varying x and y gradients perpendicular to the labeling direction in combination with phase changes of the RF pulses to create a circular labeling spot and to achieve an efficient inversion at the targeted artery. The size of the labeling spot can be adjusted by changing the moment of the applied extra gradients [1]. Unequal gradient moments of the additional gradients result in an elliptical labeling spot. In numerical simulations the impact of different gradient moments on the size and shape of the labeling spot and on the labeling efficiency was investigated and subsequently used to adapt the labeling focus to multiple vessels. ASL data based on multi-vessel labeling was used to acquire three perfusion images: One of the left circulation (LC) with combined flow territories of the left ICA and of the left vertebral artery (VA), one of the right circulation (RC) with combined flow territories of the right ICA and right VA, and one of the posterior circulation (PC) with combined flow territories of both the VAs. Individual flow territories can be calculated from this set of images by:

$ICA_{right} = (RC - PC + |RC - PC|)/2$, $ICA_{left} = (LC - PC + |LC - PC|)/2$, $VA_{right} = PC - ICA_{right}$, $VA_{left} = PC - ICA_{left}$.

In order to verify the proposed labeling scheme, a total of 8 healthy subjects was scanned applying both the original approach (labeling of each vessel separately) as well as the multi-vessel labeling approach. All measurements were performed on a clinical Philips 3T Achieva scanner using the following parameters: field of view 220x220mm, voxel size of 2.7x2.7x6 mm, gradient echo planar read-out. Labeling duration 1.65 s, postlabeling delay 1.525 s with background suppression, 18 slices and 20 averages of label and control images. Scan time was approximately 2:40 min per measurement. The perfusion-weighted images were combined into a color-encoded frame and an overlap between perfusion territories will therefore result in the mixing of two or more colors.

RESULTS and DISCUSSION: Fig.1 presents results from numerical simulation of the original approach (a) with a circular labeling spot. If unequal gradient moments are employed the labeling spot assumes an elliptical shape (b) that can be utilized for multi-vessel labeling (c) as described above. Figs.2-4 show flow territory maps of the cerebellum and of the cerebrum obtained with both the original and the multi-vessel labeling approach. The calculated flow territories were very similar to the measured territories and individual flow distribution pattern dependent on anatomical variants of the posterior circulation in the cerebellum as well as of the CoW in the cerebrum can be depicted. In the first subject (fig.2) the right VA (yellow) ends in the right posterior inferior cerebellar artery (PICA) which is the reason why only the left VA (blue) contributes to the blood supply of the posterior cerebrum. In another subject presented in fig.3 the VAs are of similar size, hence, both arteries contribute to the posterior territory which results in mixed perfusion signal whereas the blood supply of the cerebellum showed significant differences between the two VAs. Such information can be important, e.g. in stroke patients for the correlation between cerebellum infarcts and causative vessels. However, even if only the perfusion territories of the cerebrum, in particular the posterior circulation, are of interest it is still recommended to apply multi-vessel labeling to the VAs as shown in fig.1c. Subjects presenting a strongly angulated BA require an oblique planning of the labeling plane so that the blood flows perpendicularly through the labeling plane and thus to ensure optimal labeling efficiency. At the same time this may result in interference between labeling plane and image stack so that undesirable artifacts will appear in the region of interest (fig.4). Simultaneous labeling of the VAs will circumvent such problems since the labeling plane is positioned more proximally to the imaging stack (fig.4). Moreover, a larger labeling spot will potentially result in higher labeling efficiency, hence in higher SNR as compared to single-vessel labeling (fig.1) [1].

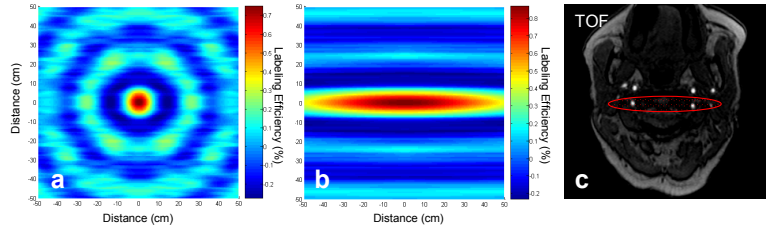

Fig.1: *a) Results from numerical simulation of the original superselective approach using equal gradient moments in x and y direction which results in a circular labeling spot (Gx=Gy=1.08 mT/m msec). b) Unequal gradient moments result in an elliptical labeling spot (Gx=0.1 mT/m msec, Gy=1.08 mT/m msec). c) The gradient moments can be adjusted in such a way that multiple vessels are labeled simultaneously.*

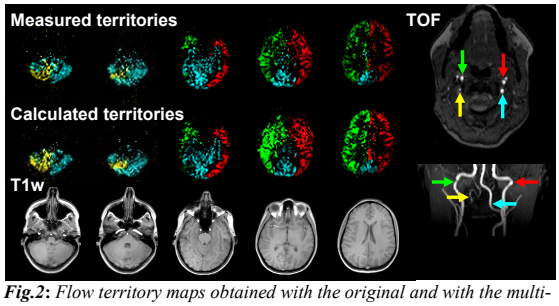

Fig.2: *Flow territory maps obtained with the original and with the multi-vessel labeling approach. The right VA (yellow) ends in the right PICA which is the reason why only the left VA (blue) contributes to the blood supply of the posterior circulation of the cerebrum.*

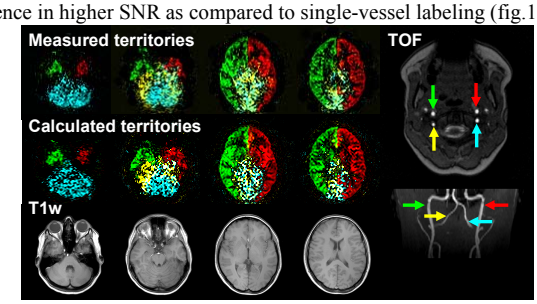

Fig.3: *Flow territory maps obtained with the original and with the multi-vessel labeling approach. Both VAs (yellow,blue) are of similar size, hence, both arteries contribute to the posterior territory which results in mixed perfusion signal. Even so, the territorial blood supply of the cerebellum showed significant differences between the two VAs.*

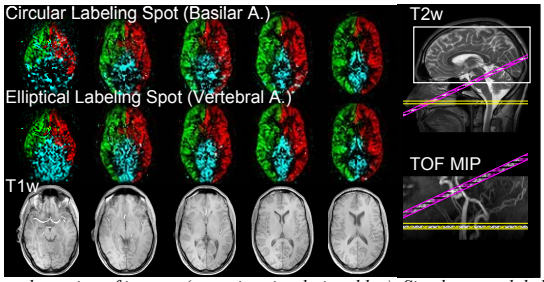

Fig.4: *Flow territory maps obtained with the original approach and with multi-vessel labeling applied to the VAs. A strongly angulated BA requires an oblique planning of the labeling plane (magenta plane) so that the blood flows perpendicularly through the labeling plane and thus to ensure optimal labeling efficiency. This may result in interference between labeling plane and imaging volume (white square) so that undesirable artifacts will appear in the region of interest (posterior circulation, blue). Simultaneous labeling of the VAs will circumvent such problems since the labeling plane is positioned more proximally to the imaging stack (yellow plane).*

REFERENCES: [1] Helle et al, MRM 2010;64:777-86; [2] Zimine et al, MRM 2006;56:1140-4; [3] Wong, MRM 2007;58:1086-91