Superselective arterial spin labeling applied for flow territory mapping in selected clinical cases - advantages over existing selective ASL methods

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Introduction

Different variants of arterial spin labeling (ASL) approaches have been developed that enable regional perfusion imaging (RPI) in a complete non-invasive way. These methods have already found widespread clinical application and made it possible to address several clinical questions regarding the diagnosis, treatment and therapy monitoring in acute stroke as well as chronic cerebrovascular disease [1,2]. However, the selectivity of existing methods is restricted and only allow for RPI in rather large vessels like the internal carotid arteries (ICAs) and the basilar artery (BA). Recently, a new method named superselective ASL has been introduced that overcomes these limitations and enables the selective labeling of smallest intracranial arteries even distal to the Circle of Willis [3]. In this abstract several cases of superselective ASL are presented to demonstrate the advantages of this method and to propose possible future applications in clinical routine.

Material and Methods

Superselective ASL is based on balanced pseudo-continuous ASL, but employs additional time-varying gradients in between the RF-pulses perpendicular to the selected artery and the in-plane angle is randomly switched after every RF pulse. By changing the phase of the RF-pulses according to the applied extra gradients efficient inversion is achieved at the targeted vessel, whereas at other positions in the labeling plane phase variations prevent inversion. By changing the moment of the added gradients, the labeling focus can be adjusted in size and adapted to various vascular architectures.

Case 1: A 57-year old male patient with a symptomatic occlusion of the left ICA underwent extra-intracranial arterial (EC-IC) bypass surgery. In this procedure an anastomosis between the superficial temporal artery (STA) and the middle cerebral artery (MCA) is created to increase cerebral blood flow. After surgery superselective ASL was applied to image perfusion territories of the right ICA, the BA, the STA and the medial meningial artery (MMA).

Case 2: In a 48-year old male patient with a symptomatic arterio-venous malformation (AVM) superselective ASL was applied to visualize the flow territories of feeding vessels prior and after surgical removal of the AVM. Since the patient developed temporal speech disorders functional MRI (fMRI) was also performed (language testing).

Case 3: A 66-year old female patient with severe intracranial stenoses and occlusions in M1/M2 segments of the MCA underwent intracranial stenting. Superselective ASL was applied before and after treatment.

For all cases, 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, 5-10 slices and 20 averages of label and control images. Scan time approximately 2:40 min.

Results and Discussion

Figure 1 shows the tagged arteries in TOF images and three representative slices of the associated perfusion territories (1.ICA, 2.BA, 3.MMA, 4.STA). It is clear that right ICA (via anterior communicating artery) and BA significantly contribute to the brain perfusion. There is a substantial contribution of the left external carotid artery (ECA) to the supply of the left lateral parietal cortex via its distal branch which is used as bypass (STA). However, the bypass does not provide blood to the complete affected hemisphere, as proven by the significant contribution of the MMA to the left frontal area. Superselective ASL made it possible to gain accurate information about the territorial distribution of cerebral perfusion and thereby about the surgical results that would not have been possible with conventional RPI techniques, but only by invasive methods like digital subtraction angiography (DSA).

Figure 2 shows the feeding vessels of the AVM in TOF images before and after surgical intervention. The diameters of the feeding vessels as well as their corresponding perfusion territories show significant changes after the removal due to decreased steal-effects of the AVM. The corresponding slices of the fMRI show Wernicke's area being supplied by the tagged arteries which may have been affected by the alteration of perfusion right after surgery and might offer an explanation for the temporal speech disorders. Superselective ASL provided important additional information by RPI exclusively of the feeding vessels of the AVM. This made it possible to track alterations to small cerebral perfusion territories and yielded possible reasons for impaired brain function which is neither accessible with DSA nor with conventional RPI methods.

Figure 3 shows intact M2 segments of the right MCA in TOF images before and after treatment. Corresponding RPI images illustrate that one M2 branch particularly supplies the sensoric motor cortex (red) which was the most decisive reason for the attempt of intracranial stenting. Stenting was successfully applied to the M1 stenosis of the MCA but failed in the M2 segment which led to total occlusion of one of the M2 branches. While the perfusion territory of the remaining branch (red) was almost unchanged after surgery the territory of the occluded branch is now supplied by collaterals originating at the anterior cerebral artery (ACA, blue) which was also proven by DSA (not shown). The detailed visualization of perfusion territories of the M2 branches by superselective ASL made it possible to assign brain tissue and function affected by a progression of vascular stenoses and thereby allowed to estimate the neccessitiy of surgical intervention.

In three selected cases the capabilities of superselective ASL are demonstrated as an important clinical tool in diagnosis, risk analysis and treatment monitoring of various diseases. Superselective ASL can yield crucial information on cerebral perfusion non-invasively that are not accessible by DSA or conventional RPI methods. Moreover, this may also contribute to a better understanding of the relation between the vasculature, perfusion, and brain function.

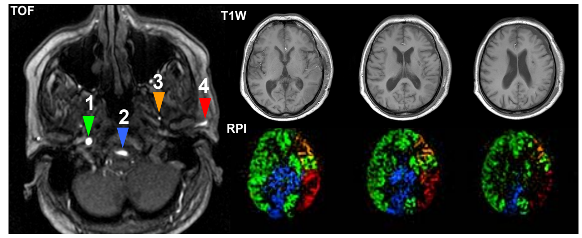

Figure 1: Images of a patient with EC-IC bypass. A TOF image shows the tagged arteries (1.ICA, 2.BA, 3.MMA, 4.STA) and RPI images illustrate the corresponding flow territories.

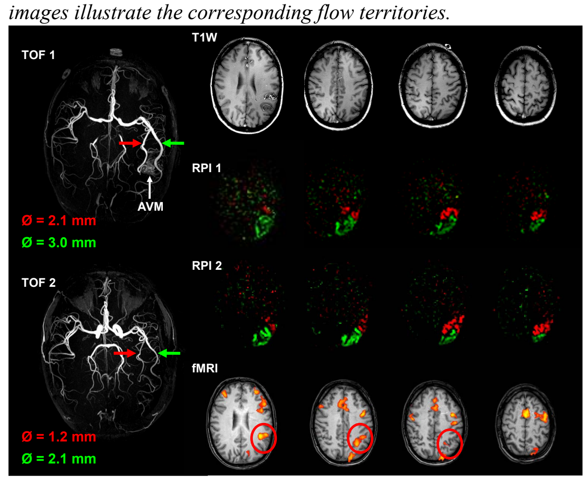

Figure 2: TOF images of an AVM patient before (TOF 1) and after surgery (TOF 2). Feeding vessels are marked with arrows. RPI images show the corresponding flow territories (RPI 1, 2) and demonstrate significant alterations after removal of the AVM. The Wernicke's area (fMRI, red circle) is supplied by the tagged vessels which might explain temporal speech disorders right after surgery.

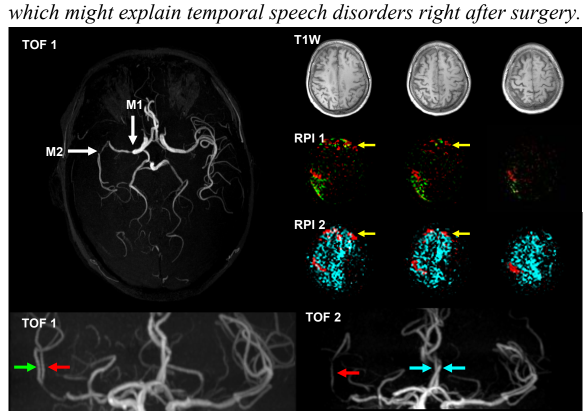

Figure 3: TOF images showing two severe stenoses (white arrows) in M1/M2 segments and intact branches of the right MCA (TOF 1). Stenting was successfully applied to the M1 stenosis but failed in the M2 segment causing an occlusion in one branch.While one perfusion territory almost remained unchanged (red) after surgery the other territory is supplied by collaterals originating the ACA (blue). Artifacts in the frontal lobe of the RPI images (yellow arrows) arose from the labeling slab impinging the imaging slices.

References: [1] van Laar et al, Radiology 2008,246:354-364; [2] Hendrikse et al, Stroke 2009, 40:1617-22; [3] Helle et al, ISMRM 2008, abstract 183