Selective Arterial Spin Labeling After Extra-Intracranial Bypass Surgery

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Introduction:

Arterial spin labeling (ASL) [1] is an important technique for the diagnosis of neurological diseases. Perfusion originating from the summed supply of all brain feeding arteries is commonly assessed. However, tagging single arteries is of interest to get additional information, e.g. efficiency estimation of a bypass surgery. One single artery is tagged to non-invasively determine the perfusion area. The purpose of our investigation was to compare a slice selective inversion of an area including only the desired vessel [2] to a multidimensional RF pulse to label only the artery of interest [3]. The advantages and disadvantages of these methods are demonstrated and compared after tagging the *internal carotid artery* (ICA) of healthy volunteers. In addition, these techniques were applied to one patient with an extra-intracranial (EC-IC) bypass to obtain its perfusion territory non-invasively.

Methods:

All measurements were performed on a 3.0 Tesla clinical whole-body MR scanner (Magnetom Tim Trio, Siemens Healthcare, Erlangen, Germany). The spatially selective two-dimensional RF pulse is based on a constant-angle spiral trajectory with n = 22 cycles. The distance of two successive cycles was $\Delta k \approx 4.5\ m^{-1}$ in order to move the first sidelobe out of the head to 22 cm. The full width half maximum of the Gaussian excitation profile was 12 mm to encompass a typical artery diameter of 4-6 mm. The total pulse duration was 13 ms. The SASL pulse sequence diagram is depicted in Fig. 1. The labeling module consists of the 2D RF pulse or a sagittal slice selective pulse, respectively. Immediately after and before the tagging pulse a saturation block was applied to eliminate the magnetization in the readout slice and to avoid direct excitation from the tagging. Between the labeling module and the standard EPI-readout, an inflow time TI is inserted. Preliminary experiments gave a maximum perfusion value for TI ≈ 1.5 s. Flow-crushing gradients were not used. The parameters of the EPI-readout were: TR = 2.5 s, TE = 44 ms, flip angle = 90°, FOV = 256 x 256 mm^2, matrix size = 128 x 128, slice thickness = 5 mm and bandwidth = 912 Hz/Px with an in-plane resolution of 2 x 2 mm^2. The control image was achieved by omitting the tagging pulse. The tag and control image were averaged over 60 images resulting in a total scan time of 5 min. The measurements were performed by tagging the ICA of probands with both SASL approaches. The perfusion values were normalized ($\Delta M/M_0$) to the baseline image to obtain the relative perfusion while the values outside of the head were set to zero. For the bypass patient sequence parameters were: TR = 2.5 s, TE = 25 ms, flip angle = 90°, FOV = 256 x 256 mm^2, matrix size = 84 x 84, slice thickness = 6 mm and bandwidth = 1190 Hz/Px with an in-plane resolution of 3 x 3 mm^2. The control and tag image were averaged 40 times resulting in a total scan time of 3 min 20 sec. A digital subtraction angiography was performed for comparison of the perfusion area.

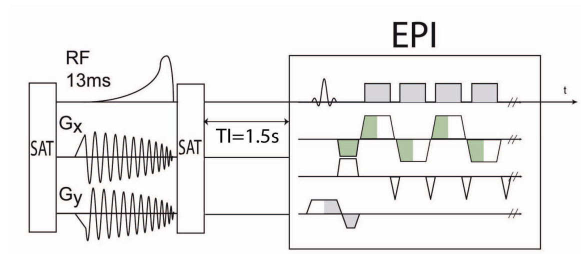

***Figure 1**: SASL pulse sequence scheme. The labeling module consists of the tagging pulse and two saturation blocks (SAT). After an inflow time TI, signal was acquired with an EPI sequence.*

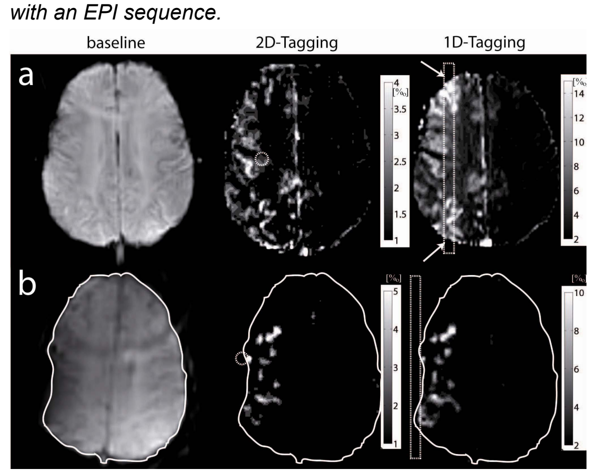

***Figure 2**: Perfusion measurement with both SASL methods. The mean baseline image (left) and perfusion maps using 2D-tagging (center) and slice selective inversion (right) are depicted. Tagging the right ICA (a) and bypass (b), perfusion signal only exists in the according hemisphere of the brain. The dashed marks demonstrate the tagging areas. The signal in the overlapping region is increased (arrows) for 1D-tagging.*

Results:

The mean baseline image and the normalized perfusion images after tagging the right ICA of a proband with both SASL methods are depicted in Fig. 2a. The transversal readout slice was set right above the *corpus callosum*. The dashed marks show the tagging areas. Perfusion is visualized in the main areas corresponding to the *middle* (MCA) and *anterior cerebral artery* (ACA). In the overlapping area of the tagging slice and the edge of the head signal is increased (arrows). The results for the bypass patient are depicted in Fig. 2b. In contrast to the proband, perfusion signal is only visible in the central part of the territory of the MCA, while there is no perfusion seen in the ACA. This corresponds to the territory perfused by the bypass, as measured by digital subtraction angiography (Fig. 3).

Discussion:

We reported that selective ASL imaging with an in-plane resolution of 2 x 2 mm^2 is possible in a total scan time of 5 min. If there are many vessels nearby, 2D RF tagging is preferred to ensure spatial selectivity. In the special case of tagging the bypass, for several reasons better results are achievable by slice selective inversion. Firstly, there are no close arteries which could be tagged unintentionally. Secondly, the bypass does not run linearly but in a plane. This means that 1D tagging results in more blood inversion compared to the other technique. But if the tagging slice overlaps with the readout slice, increased signal can be obtained due to no perfect saturation.

It was demonstrated that the perfusion measured by these SASL methods is consistent with a standard angiography. Therefore, these presented MR techniques may in part replace the assessment of revascularization success by conventional angiography.

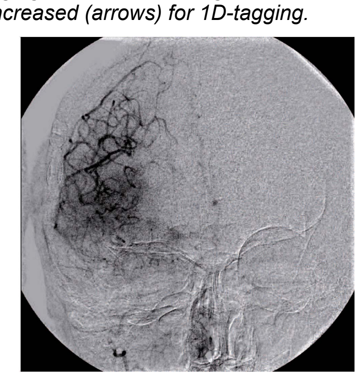

***Figure 3**: Digital subtraction angiography of the bypass patient.*

References:

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