Can arterial spin labeling detect white matter perfusion?

W. M. Teeuwisse[1], M. A. van Walderveen[1], J. Hendrikse[2], M. A. van Buchem[1], J. van der Grond[1], and M. J. van Osch[1]
[1]Radiology, Leiden University Medical Center, Leiden, Netherlands, [2]Radiology, University Medical Center Utrecht, Utrecht, Netherlands

Introduction

Recently there has been much discussion about the capabilities of arterial spin labeling (ASL) to quantify white matter (WM) perfusion and/or to detect perfusion deficits in the WM.[1] Several new advances in ASL methodology, like the introduction of pseudo-continuous ASL and background suppression, have led to increases in the SNR of the resulting perfusion maps.[2,3] Furthermore, Wong *et al* have introduced a technique, velocity selective ASL, that is less sensitive for delay effects that affect especially perfusion measurements in the deep WM.[4] The goal of the current study was to investigate whether WM perfusion imaging by ASL becomes feasible by employing these advances. This was investigated in healthy volunteers as well as in patients with arteriovenous malformations (AVM).

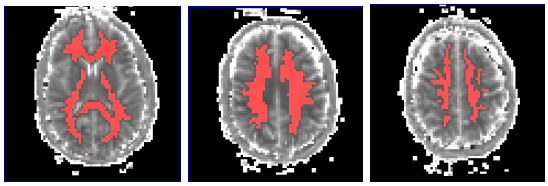

Figure 1: White matter segmentation projected on quantitative T_1-map.

Methods

Pseudo-continuous ASL (labeling duration 1.65 s, postlabeling delay 1.525 s with background suppression, 15 slices, voxel size 3x3x7 mm, duration 10 min) and velocity selective ASL (cut-off velocity of 2 cm/s, postlabeling delay 1.6 s, background suppression, 15 slices, voxel size 3x3x7 mm, duration 10 min) were performed on 5 volunteers (age 24-49 years). Additionally, a second pseudo-continuous ASL was performed (n=4) with a longer labeling and delay time (resp. 2.5 s and 1.9 s, scan duration kept constant) to make the acquisition less delay-sensitive. Finally, a pseudo-continuos ASL scan was made with the labeling plane located above the imaging slices as a control experiment to identify potential subtraction errors. All images were registrated to correct for motion. Hereafter, it was tested for every voxel (double sided t-test, $p<0.05$) whether the ASL signal over time was significantly different from zero. Based on a quantitative T_1 scan, acquired at the same resolution as the ASL images, a conservative WM mask was created (see Figure 1) and the percentage voxels that showed ASL signal significantly different from zero was determined. Finally, pseudo-continuous ASL was performed in a patient with an AVM (same parameters, scan duration 4 min) and compared to DSC perfusion MRI (bolustracking MRI).

Table 1: Percentage WM voxels with significant signal

	Percentage of WM voxels with statistically significant signal
Pseudo-continuous ASL	71 ± 10 %
Velocity selective ASL	68 ± 7 %
Pseudo CASL long labeling and delay time	59 ± 8 %
Pseudo-CASL labeling above imaging	3.6 ± 0.6 %

Results

Table 1 shows that the majority of WM voxels showed ASL signal that is significantly larger than zero. Subtraction errors cannot explain these findings, since labeling above the imaging resulted in 5% voxels unequal to 0; which corresponds to the used p-value of 0.05. Increasing the labeling and delay time of the pseudo-continuous ASL sequence did not lead to improved perfusion imaging in the WM. In an AVM patient, bolus-tracking perfusion MRI showed no CBF perfusion deficits in the WM, but did show late contrast agent arrival in the WM (see yellow arrows). The ASL images show clear hypo-intense signal in the corresponding WM regions (see white arrows in Fig. 2, ASL signal is only 25% of the contralateral WM).

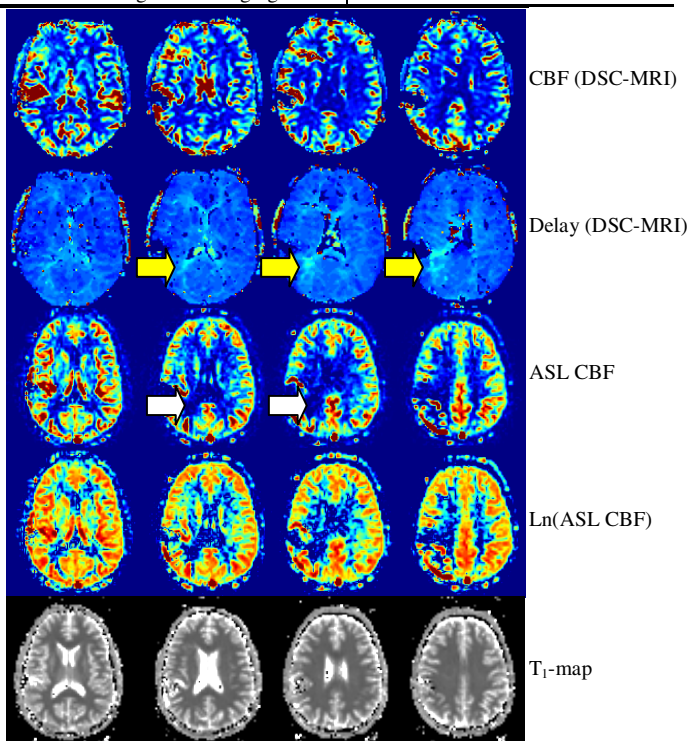

Figure 2: Perfusion imaging in a patient with an arterial venous malformation. Bolustracking perfusion MRI (upper two rows) do not show CBF deficits in the white matter, but an increased delay in contrast agent arrival (yellow arrows). The region of increased delay is depicted as a hypo-intense region in the ASL data (see white arrows).

Discussion and conclusions

Both the measurements in normal volunteers and in an AVM patient, show the capabilities of ASL to detect WM perfusion. The applied imaging sequence has a relatively low spatial resolution, therefore some partial volume effects would occur near the cortical gray matter. To avoid this confounding effect we used a rather conservative segmentation of the WM (e.g. see Fig. 1). Finally, the ability to identify hemodynamic changes in the WM of an AVM patient can be considered to be the ultimate proof that ASL can identify perfusion deficits. However, DSC-MRI showed that these hypo-intensities are probably not attributable to decreased CBF but rather to increased transport times of the labeled spins.

References: [1]Van Gelderen, ISMRM 2007 (p. 1416) [2] Wu MRM 1020-1027 (2007) [3]Ye, MRM 92-100 (2000) [4]Wong MRM 1334-1341 (2006)