

## Comparison of ASL and PWI perfusion in stroke patients

E. T. Petersen<sup>1,2</sup>, T. C. Lim<sup>2</sup>, N. Venketasubramanian<sup>2</sup>, and X. Golay<sup>2,3</sup>

<sup>1</sup>Center of Functionally Integrative Neuroscience, University of Aarhus, Aarhus, Denmark, <sup>2</sup>National Neuroscience Institute, Singapore, <sup>3</sup>Institute of Neurology, University College London, United Kingdom

**INTRODUCTION:** Arterial Spin Labeling (ASL) uses magnetically labeled water protons as an endogenous tracer. This makes ASL difficult to apply in case of prolonged transit times from the labeling region to the image region, as often seen in stroke patients, because the label vanishes with the T1 of blood. In addition, the low signal-to-noise ratio in ASL experiments necessitates long averaging with borderline sensitivity in white matter, and makes it questionable whether it can contribute to stroke imaging at all [1]. Certain ASL methods, such as QUASAR [2] can also provide information beyond ordinary Cerebral Blood Flow (CBF), similar to the gadolinium-based perfusion methods (PWI). These include information such as arterial blood volume, transit times of blood traveling from the labeling plane to the region of interest. The enticement for using ASL in stroke comes from its basic quantitative nature as compared to gadolinium-based perfusion methods. It is also cheaper and free of contrast related complications such as nephrogenic systemic fibrosis. In this work, we compare information obtained with standard gadolinium-based perfusion methods to that obtainable using arterial spin labeling techniques in first stroke patients.

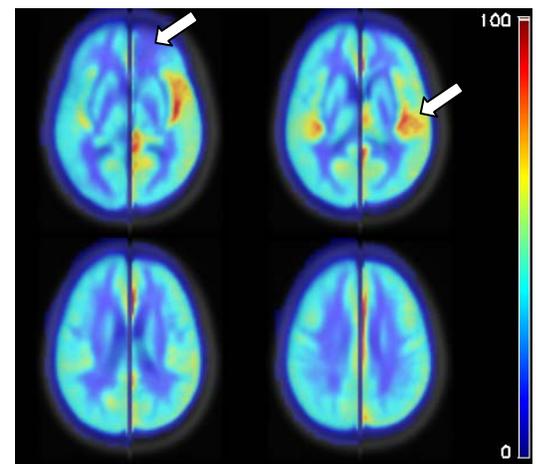
**METHODS:** All experiments were approved by the local ethics committee and performed using a 3T Philips Achieva system. 159 patients (67 females, 92 males, age 25 to 89, mean=59) with first time stroke were recruited for this study and scanned 3.4±2.2 days after onset. The protocol consisted of PWI, DWI as well as ASL scans. ASL scan parameters: TR/TE/□TI/TI1=4000/23/300/40ms, 64x64 matrix, 7 slices (6mm + 3mm gap), FOV=240x240, flip-angle=35/11.7°, SENSE=2.5. Venc=[∞,4 cm/s], 84 (48 @ Venc=4cm/s, 24 @ Venc=∞, 12 low flip angle) averages, all implemented in a single sequence. Total scan time 5:45. PWI scan parameters: TR/TE=1575/45ms, 96x96 matrix, 21 slices (5mm + 1mm gap), FOV=240x240, flip-angle=65°, SENSE=2.5. The ROIs of the DWI-visible lesions as well as all perfusion maps were registered to MNI space. Data where both ASL (119 -75% success) and PWI (124 - 78% success) images were of diagnostic quality and with semi-hemispheric lesions were included (N=87). Normal CBF maps were calculated from non-infarcted hemispheres for ASL and PWI and the PWI images were normalized according to mean gray matter (GM) values of ASL. Semi-hemispheric lesions larger than 8cc were included for analysis (N=16). The infarct core as well as the peripheral region spanning 0.8 cm around the core was analyzed regardless of it being penumbra, normal or luxury perfusion area. ROI ratios from ipsi/contra-lateral side were calculated for the two regions and for all ASL and PWI perfusion maps for comparison.

**RESULTS and DISCUSSION:** Fig. 1 shows the average perfusion map for both ASL (left side) and PWI (right side) on four different slice levels. Generally, identical relative perfusion information is obtained in healthy tissue, except in the lower frontal area where PWI suffers from signal dropout, and areas of larger feeding vessels showing unrealistic high values of CBF. For the infarct core and surrounding there were no significant GM CBF differences between ASL and PWI ( $p > 0.05$ ). Figure 2 shows the ratios for ipsi/contra-lateral perfusion for the infarct core (squares) and the peripheral region (triangles). In red the PWI-CBF ratios versus ASL-CBF ratios are depicted. There is a good agreement between the two modalities ( $r = 0.6$ ). The presence of perfusion ratios  $> 1.0$  can be explained by the fact that most scans were performed late after stroke onset (2.9±1.2 days in this subset), at a time where reperfusion might have occurred in many of the patients. For the peripheral region, the majority of perfusion ratios clusters around unity which is considered normal perfusion, a few show higher ratios suggesting luxury perfusion and a single one is lower which could be a persistent penumbra area. In orange the ratios for arterial transit time (ATT) in ASL and time to peak (TTP) in PWI show some agreement in the peripheral area ( $r = 0.5$ ) but not in the core ( $r = 0.2$ ). Although, ATT and TTP both represent the bolus arrival, ATT would tend to be less reliable with increased arrival times because the label tag gets smaller or even disappears before arrival. Alternatively, TTP represents a mixture of MTT and ATT, and in regions of abnormal perfusion, both methods would likely disagree. However, it should be noted that both modalities always shows normal or prolonged arrival times. On the other hand, the arterial blood volume (aBV) in ASL and cerebral blood volume (CBV) in PWI (in blue) shows no correlation either at the periphery ( $r = -0.5$ ) or in the core ( $r = -0.4$ ) of the infarct. Although ASL only measures the arterial contribution to the CBV, one could expect that in diseased areas, aBV would go up along with CBV due to the local auto regulation, which should lead to a good correlation between both methods. This will be investigated in future studies.

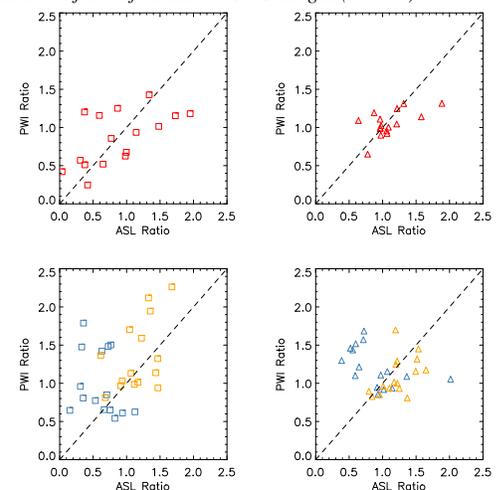
**CONCLUSION:** One of the major problems with the use of ASL in stroke relates to the limited time span of the label, and makes it arguable whether it will have clinical applicability as compared to PWI imaging for estimation of the penumbra. However, in this work we have shown that ASL acquired at multiple time points using the QUASAR sequence [2] can provide similar information to PWI in the affected areas. In addition, the method can also be adapted to probe the existence of collateral perfusion [3] and both techniques combined could potentially be valuable in this risk assessment. Nevertheless, it remains to future studies of hyperacute stroke where adequate information about final outcome is available to tell whether ASL eventually can prove reliable and sufficient in acute stroke.

**REFERENCES:** [1] Petersen et al, BJR 2006;79:688–701 [2] Petersen ET et al, MRM 2005;55:219-32 [3] Hendrikse et al., Stroke 2004;35:882-887

**ACKNOWLEDGEMENT:** NNI patient recruitment team, NMRC/0919/2004



**Figure 1.** CBF maps from non-infarcted hemisphere have been registered to MNI space (N=87). In every slice, the left side shows the maps based on ASL and the right side shows the maps based on gadolinium PWI. Notice the dropout in the lower frontal area as compared to ASL and the large vessel artifacts often seen in PWI images (arrows).



**Figure 2.** Perfusion ratios (ipsi/contralateral ROI). Squares are for the infarct core and triangles are in for periphery of the infarct. In red the PWI-CBF vs ASL-CBF, in blue PWI-CBF vs ASL-aBV and finally in orange PWI-TTP vs ASL-ATT