Improved detection and estimation of perfusion using high spatial resolution ASL at 7T

E. L. Hall[1], R. Wesolowski[1], P. A. Gowland[1], and S. T. Francis[1]

[1]Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

INTRODUCTION**:** Arterial Spin Labelling (ASL) data is typically acquired at coarse resolution with voxel volumes of ~ 50 µl. At this spatial resolution the detection and estimation of grey matter perfusion is limited by partial volume effects (PVE). Ultra-high field (7T) provides increased signal-to-noise (SNR) and ASL data has increased contrast-to-noise (CNR) due to lengthened relaxation times [1]. These gains can be exploited to acquire ASL data at high spatial resolution and here the advantages are assessed.

METHODS: *Acquisition:* Data was acquired on a Philips Achieva 7.0 T scanner (head volume transmit and 16-ch SENSE receive coil) using a FAIR scheme (selective inversion 10 mm wider than imaging volume, 250 mm spatially limited non-selective inversion [1], optimised WET pre-saturation and sinc post-saturation scheme for in-plane saturation) and GE-EPI acquisition. EP images were acquired using SENSE factor 2 and half scan 0.8 to achieve a 16 ms echo time at all spatial resolutions (constant bandwidth per pixel in phase-encode direction). In a single scan session data was acquired at spatial resolutions of: 3 x 3 x 5 mm^3 (45 µl), 3 mm isotropic (27 µl), 2 x 2 x 3 mm^3 (12 µl), and 1.5 x 1.5 x 3 mm^3 (7 µl). 5 contiguous axial slices were acquired in ascending order with minimal temporal spacing. All data was acquired using background suppression (two inversion pulses at TI1 = 402 ms and TI2 = 639 ms), to reduce physiological noise [2], with labelling delay of 1550 ms, and TR = 4.8 s per pair. Also acquired were a high resolution IR-EPI (1.5 x 1.5 x 3 mm^3, TI: 100 – 2500 ms) for T_1 mapping, high resolution T_1-weighted MPRAGE data (0.5mm isotropic) for segmentation of tissue types into partial volume (PV) maps, and field maps for distortion correction of PV maps to ASL data space.

Analysis: At each spatial resolution, images were realigned and difference (ΔM) images averaged and normalised (ΔM/M). MPRAGE images were segmented into grey matter (GM), white matter (WM), and CSF partial volume images using the FAST segmentation (FSL) and GM PV maps co-registered to each spatial resolution ASL data. At each spatial resolution grey matter masks were formed from the ΔM/M images at a threshold level of 0.375 % (loose mask) and 0.775 % (restricted mask). For each mask mean ΔM/M signal was calculated for each spatial resolution and PV maps used to correct the ΔM/M signal on a voxel-by-voxel basis.

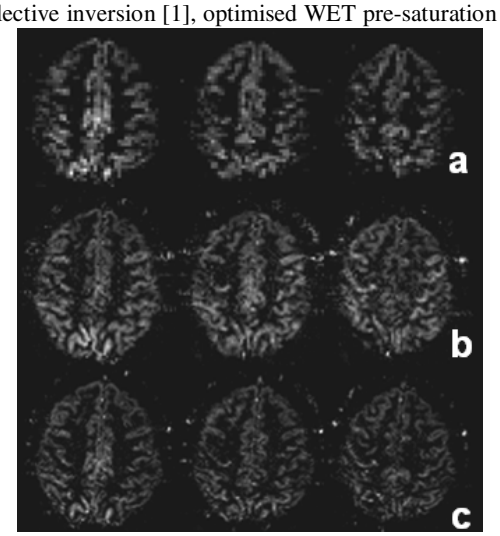
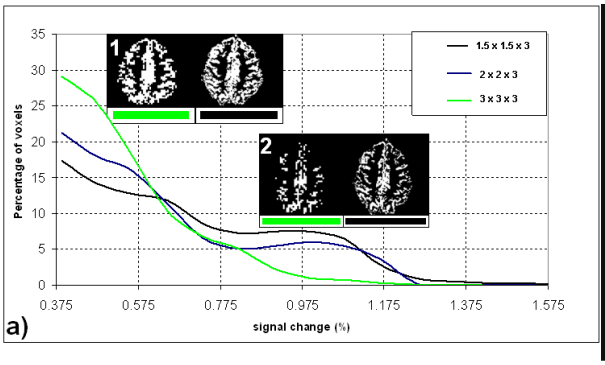


Figure 1: *Perfusion weighted (ΔM) images at (a) 3 mm isotropic, (b) 2 x 2 x 3 mm^3, (c) 1.5 x 1.5 x 3 mm^3.*

RESULTS: Figure 1 shows multi-slice ASL perfusion weighted (ΔM) images at three spatial resolutions (27 µl, 12 µl and 7 µl). High spatial resolution provides good delineation of cortical GM and increased homogeneity in GM. Figure 2 plots a histogram of the percentage of voxels in the loose GM mask (Fig.2 inset (1)) with a given ΔM/M signal change (0.1 % bins). At all spatial resolutions the greatest percentage of voxels is in the low ΔM/M band, with the course spatial resolution (green) having a larger percentage of voxels in the low (0.375 -0.575 %) ΔM/M range compared to a high spatial resolution. The high spatial resolution data shows a significant peak in percentage of voxels with ΔM/M in the range 0.775 and 1.175 % compared to coarse resolution. The restricted GM mask (Fig. 2 inset (2)) shows that at high resolution it is possible to define a threshold to delineate GM voxels (reducing PV effects) across the whole cortex, while at coarse resolution this is not possible since GM homogeneity and sensitivity is reduced. Table 1 shows the variation in mean GM ΔM/M signal change with spatial resolution for both the loose and restricted masks. High resolution data provides sufficient sensitivity to localise GM voxels with high PV levels leading to improved estimation of GM ΔM/M and thus perfusion rate. Figure 2b highlights that PV effects can both lead to elevated ΔM/M signal (green), in regions of closely folded cortex, and reduced (red) signal and spatial localisation of cortex, for example within the motor cortex, as highlighted.



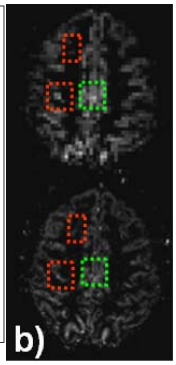


Figure 2: a) *Histogram of % of GM voxels at each ΔM/M signal change for different spatial resolutions. (1) Loose GM mask (2) Restricted GM mask* ***b)*** *ROI with PV effects leading to elevated (green) and reduced (red) ΔM/M signal*

Resolution (mm)	Loose Mask		Restricted Mask	
	(ΔM/M)%	Mean PV	(ΔM/M)%	Mean PV
1.5x1.5x3	0.70 ± 0.14	0.57	0.95 ± 0.06	0.87
2x2x3	0.65 ± 0.12	0.54	0.94 ± 0.10	0.83
3x3x3	0.61 ± 0.21	0.52	0.84 ± 0.20	0.67

Table 1*: Effect of spatial resolution on ΔM/M for loose and restricted grey matter masks.*

DISCUSSION: High spatial resolution ASL at 7T allows improved delineation of grey matter. The reduced partial voluming in grey matter leads to improved ASL contrast-to-noise, and increased measured signal change and therefore perfusion rate. The improved spatial resolution will allow more accurate estimation of perfusion, for example to comparing young and elderly subjects and detect infarcts, and location and estimation of functional changes.

REFERENCES: [1] Gardener et al., MRM, 2008 (in press), [3] Garcia et al., MRM, 54,336-372, 2005.

Acknowledgements: This work was supported by the MRC.