Arterial Spin Labelling in the Human Placenta – Mapping Perfusion

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Background – The placenta is critically important in pregnancy for the supply of nutrients and oxygen to the fetus and the removal of waste products. If these functions are disrupted the fetus may fail to fulfill its genetic growth potential resulting in the condition of fetal growth retardation (FGR) increasing the risk of medical complications at birth and in later life. This condition may be caused by a number of genetic and environmental factors which result in disruption of the placental morphology [1] affecting function. As the placenta is a very vascular organ, the perfusion is a parameter that may be affected by such morphological changes. Perfusion may be measured non-invasively by Magnetic Resonance Imaging (MRI) using Arterial Spin Labelling (ASL). ASL has been applied in pregnancy previously at low field strength (0.5 T) [2]. Advances in ASL methodology and higher field strengths allow for more detailed investigation of placental flow characteristics particularly at a voxel level since inhomogeneity in placental perfusion may be as a result of structure which must be categorized before FGR can be investigated.

Methods – Flow-sensitive Alternating Inversion Recovery (FAIR) [3] ASL was selected because the labelling of all the blood outside of the imaging slice, both maternal and fetal flow, gave the maximum possible contrast between the labelled and unlabelled images. The sequence used is based on current methodology [4] adapted to use a Half-Fourier (55%) Single-shot Turbo spin Echo (HASTE) readout. Scanning was carried out using a 1.5 T Philips Intera system (Philips Medical Systems, Best, NL) using the cardiac coil. Images were collected for 7 different inversion times (300, 600, 900, 1200, 1500, 1800 and 2300 ms) each with 21 averages and a non-inversion acquisition for initial magnetization (M0). Parameters were TR/TE=3500/5.4ms; FOV=384x384mm; single slice with voxel dimensions 3x3x8 mm^3 with limitations on SAR and noise. The slice was selected perpendicular to the maternal fetal axis. The slice selective inversion was 20 mm outside the imaging slice and the non-selective inversion 400mm. Imaging was carried out in 9 pregnant women all with clinically normal pregnancies during their third trimester. Individual images affected by motion were excluded from analysis. Model fitting was carried out using the Buxton Model [5] as a two parameter fit with an assumed infinite bolus end. This was applied in a region (673-2862 voxels) defined within the placenta to be free from artifacts, to both the mean signal differences observed in the ROI and also on a voxel by voxel basis. An ROI curve is shown in Figure 1 and the flow map overlaid in Figure 2 for the same subject. The single perfusion value from the ROI fitting was compared with the mean of the voxels in the region.
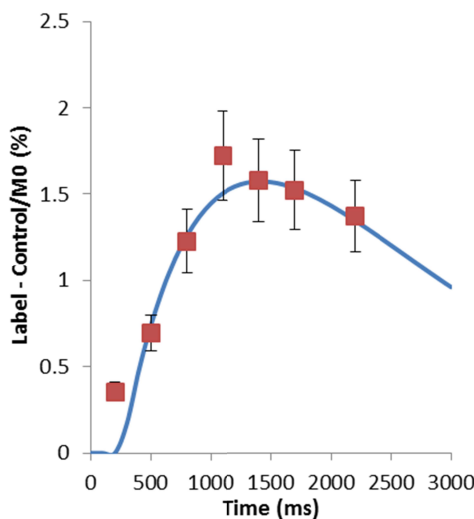

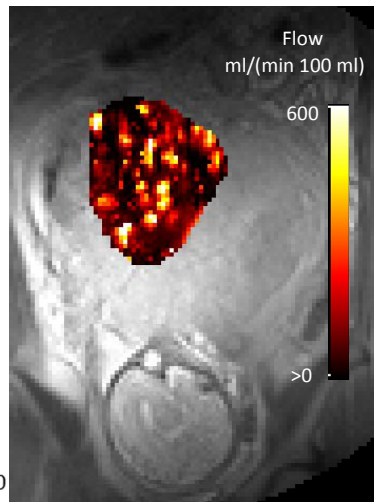Fig 1: ROI signal difference values ■ with model fit line - and standard error bars

Fig 2: ROI defined on a coronal structural image with flow map overlaid
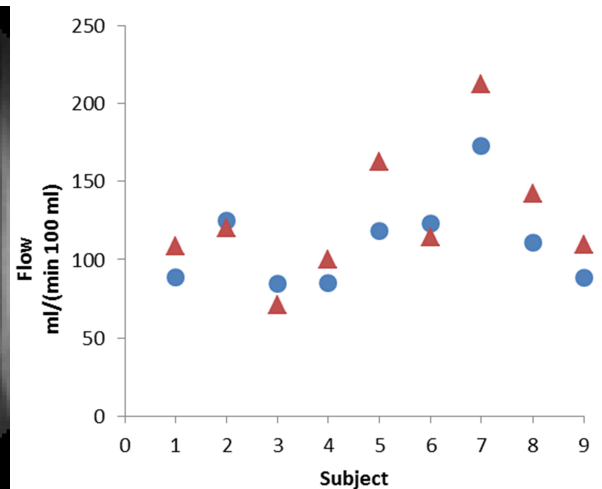
Fig 3: Comparison of flow values from ROI fits (circles) and voxel fits (triangles)

Results – For n=9 the perfusion values in ml/(min 100 ml) (mean ± standard deviation) for the ROI fitting the mean signal were 111 ± 29 ml/(min 100 ml) and for the mean of the voxel by voxel results 127 ± 47 ml/(min 100 ml). The difference between the methods can be seen graphically in Figure 3. There is no significant difference between the results observed but a trend towards the voxel by voxel fits being higher P=0.051 (Wilcoxon signed rank test) which they are in 6 of 9 cases.

Discussion – These results show reasonable agreement with the previous work [2] (176 ± 24 ml/(min 100 ml)) and are closer to values of placental perfusion from other modalities. The similarity of the ROI and voxel values suggests the voxel results are not adversely affected by noise, while structure observed in the maps indicates that differential perfusion is a feature of normal placental function. These initial results suggest that the implementation of the FAIR-HASTE ASL can be used successfully in the challenging placenta environment to map inhomogeneity and may in the future be applied to the investigation of FGR.

References – [1] Sibley et al Paed. Res. 58: 827-32 2005. [2] Gowland et al MRM 40:467-473 1998. [3] Kim MRM 34:293-301 1995. [4] Garden & Francis MRM 63(6):1627–1636, 2010. [5] Buxton et al. MRM. 40:383-396 1998.