Assessment of placental blood flow using a navigator echo respiratory gated parallel imaging technique at 1.5 T

L. S. Truica[1], I. Cameron[1,2], L. I. Avruch[2], and A. Gruslin[2]

[1]Carleton University, Ottawa, ON, Canada, [2]The Ottawa Hospital, Ottawa, ON, Canada

Introduction: Fetal and maternal blood flows in the placenta at the same time; the fetal blood in the vessels of the placental villi and the maternal in the intervillous space. A few studies have shown that placental blood flow can be assessed with DWI[1,2,3], however, there is a need for improved acquisition and analysis tools. The results reported here were acquired with parallel imaging and respiratory triggered non-breath hold sequences.

Methods: Imaging was done on a Siemens Symphony–TIM 1.5 T scanner with 30 mT/m gradients using the phased array torso matrix coil. 8 pregnant women (23 to 37 yrs old) were recruited. The study had IRB approval and informed consent was received from all subjects. At imaging all were considered to have normal placentas. DWI of the entire placenta was done using a respiratory triggered DW_SS_EPI sequence with: TR=3080-5866 ms, TE=94 ms, FOV=350-450 mm, phase FOV=75%, 144x192 matrix, iPAT-GRAPPA factor=2, eighteen 10 mm thick axial slices (2.5mm gap), total imaging time=124 s, diffusion gradients were in the slice select direction, spectral fat saturation was used and 13 b-values: 0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 650, 800 s/mm^2.

Analysis: Data analysis assumed the IVIM model[4,5,6]., which considers water diffusion and blood microcirculation as separate components of the diffusion decay:

Fig 2 Maps: a) f, b) D^* and c) D

$$S / S_0 = (1 - f) \exp(-bD) + f \exp(-bD^*) \quad [1]$$
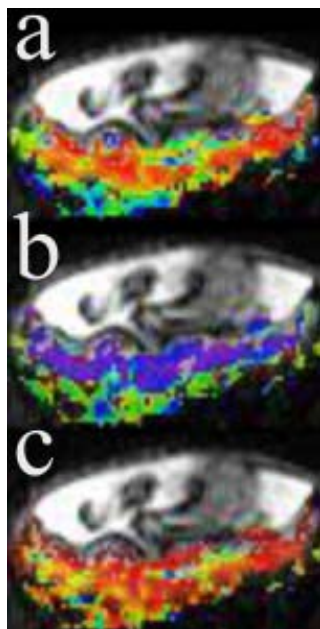
where S is the DW signal, S_0 is the b=0 signal, D and D^* are the diffusion and pseudo-diffusion coefficients, respectively, and f is the perfusion fraction. Diffusion decays for 3 100-pixel rectangular ROIs were fit to Eq 1 to evaluate D, f, and D^*. The ROIs were positioned carefully to avoid areas where fast flowing maternal blood enters the placenta. In a separate analysis a larger ROI was drawn around the whole placenta. D, D^* and f maps were calculated pixel-by-pixel and color overlaid onto an anatomical image.

Results and Discussion: Fig 1 shows the fit parameters for whole placenta and 100-pixel ROIs vs. gestational age (GA). f and D do not change with gestational age. It is well known that placental growth parallels fetal growth so a constant f value throughout the pregnancy is expected. The fractional volume of intervillous space relative to the total villous plus intervillous volume ≈0.5[7] in agreement with our values. The parameter values vary as a function of ROI position in the slice, as
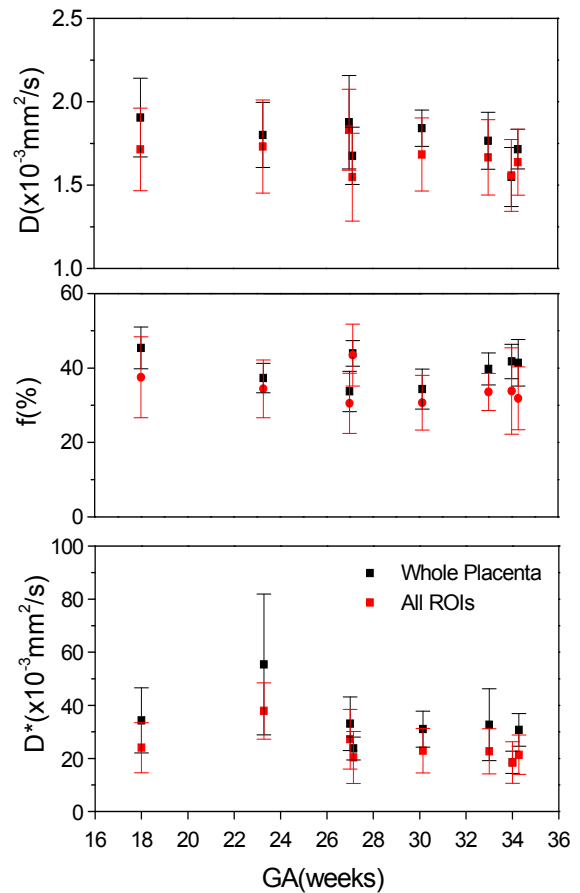

Fig 1 Fit parameters vs. gestational age for 1) whole placenta and 2) the mean of 3 100-pixel ROIs (mean ± SD).

well as from one slice to another; however, this variation is within measurement error and the values are close to the whole placenta values. The smaller variation for the whole placenta ROI compared with the 100 pixel ROIs is to be expected since it has a larger number of pixels. Fig 2 shows color maps of f, D^* and D. The range on the color table is: a) f (0-100)%, b) D* (0-80) x10^{-3}mm^2/s and c) D (0-2) x10^{-3}mm^2/s.The area where maternal blood spurts in from the spiral arteries can clearly be seen.
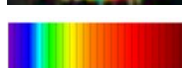
D^* showed the largest range of values. These large variations were observed for the whole placenta ROI and between patients as well but they were not as large as for other studies in the literature. D^* is directly related to the velocity of the circulating fetal blood and the length of the randomly oriented capillary segments; there will be a large number of capillaries in the voxel. At the same time, about 150 ml of maternal blood is flowing in the intervillous spaces and exchanges 3 or 4 times a minute[8]. The value of D^* is affected by both systems. To within experimental error, all patients had the same parameter values. The mean values for the fit parameters for the whole placenta averaged over all volunteers were: D=(1.761±0.215) x10^{-3} mm^2/s, D^*=(30.30±11.65) x10^{-3} mm^2/s, and f=(39.46±6.36 %). The error in fitting the IVIM parameters was improved in all cases, to close to half the errors reported previously. The large variation of the values reported in the literature is probably related to different protocols used, different algorithms used for image analysis, GA and the health of the placenta when investigated or different experimental set-ups and MR scanners used for the data acquisition.

Conclusion: The improvements in data acquisition and analysis presented in this study provided more consistent results for f, D^* and D for normal placenta than previously reported studies. Parameter maps of the true diffusion coefficient D and the perfusion fraction f were reflective of placenta structure and tissue composition. Fit parameter maps can be a useful tool in identifying differences in tissues and give important insight into the hemodynamic systems present in the placenta. This technique could become instrumental in the assessment and management of abnormal pregnancies.

References:
1. Moore et al, *Magn. Res. Med.* 2000; 43:295-302
2. Moore et al, *Placenta* 2000; 21: 726-732
3. A. M. Al-Radaideh1et al, *Proc. Intl. Soc. Mag. Reson. Med.* 2009; 17
4. Le Bihan et al, *Magn Reson Q* 1991; 7:1–30
5. Le Bihan et al, *Radiology* 1988; 168:497–505
6. Le Bihan et al, *J. Com. Ass. Tomo.* 1991; 15:19-25
7. Mayhew et al, *Placenta* 1994; 15:209-217
8. Gray H, *Anatomy of the Human Body*, 15th Edition, Chancellor Press, 1994