Measuring Coherent Blood Flow in the Placenta, Basal Plate and Chorionic Plate

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Introduction: The placenta is essential for ensuring optimal fetal growth and development but there are limited methods available for assessing its function in vivo. Uterine artery and umbilical artery blood flow can be measured with Doppler ultrasound, placental perfusion can be measured with ASL[1] and placental moving blood fraction can be measured with power Doppler ultrasound and IVIM[2]. However, coherent flow within the placenta and uterine wall are rarely reported with ultrasound. The relationship between coherent velocity and moving blood volume is important for understanding placental function. In normal pregnancy the spiral arteries of the placenta remodel to give high volume, low resistance, low velocity blood flow in the placenta. However, in compromised pregnancy high resistance, high velocity, low flow can result. Furthermore it would be interesting to investigate the relationship between arterial and venous blood flows through the placenta

Aim: To measure blood flow velocity in the uterine wall and placenta.

Methods: Scanning: Following ethics committee approval, 6 healthy pregnant women and 3 with Type 1 diabetes from Queen's Medical Centre Nottingham were recruited and gave informed consent to participate in the study. Of these subjects, 7 were scanned at 24–26 weeks and 5 were scanned at 34–36 weeks gestational age (GA), using 1.5 T Philips Achieva MRI scanner with 5-element SENSE cardiac coil or 4-element SENSE torso coil, depending on the woman's size. Women generally lay on their right side to avoid vena cava compression and all scans were conducted with a specific absorption rate of < 2.0 W kg^{-1}. A respiratory gated, flow encoded EPI sequence (2 interleaves) was used to minimise problems associated with fetal and maternal motion (TR = 3000 ms, TE = 109 ms, resolution = 2×3×7 mm^3). This was implemented using the DTI code at low b values giving effective velocity encoding, Venc = 1, 5, 10 and 23 cm s^{-1} for flow in three directions parallel to the scanner axes (Figure 1). Data were acquired in 5 slices encompassing the placenta and parallel to the scanner axes to aid interpretation of data. Analysis: The magnetic field homogeneity is generally very good inside the pregnant uterus (approximately sphere of relatively uniform magnetic susceptibility—Figure 1B), so no phase unwrapping was required at low Venc and no low Venc and no low pass filtering were applied at this stage when the spatial frequencies of the coherent flow patterns within the placenta remain unknown. A ROI was drawn along the basal plate and in a neighbouring region in the placenta (Figure 2) to compare the flow distribution in the two regions. Histograms of flow in these two ROI were subtracted for comparison.

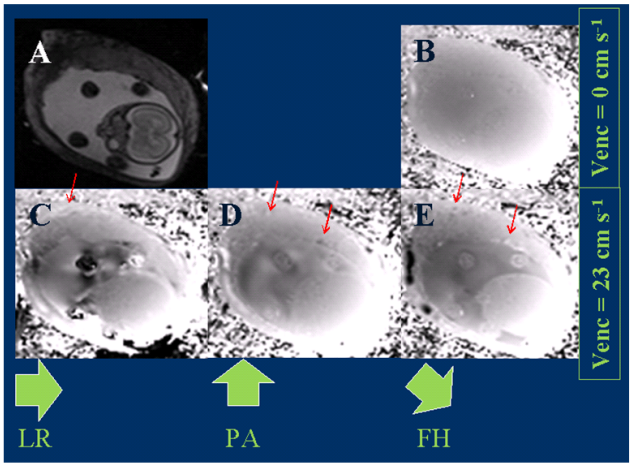

Figure 1: Control subject (25 weeks) showing the magnitude image (A) and corresponding phase image (B) for no flow encoding in 1 slice. Also the flow encoded images (Venc = 23 cm s^{-1}) for left right (C), posterior anterior (D) and foot head (E) flow. Arrows indicate some areas of high flow in the basal plate

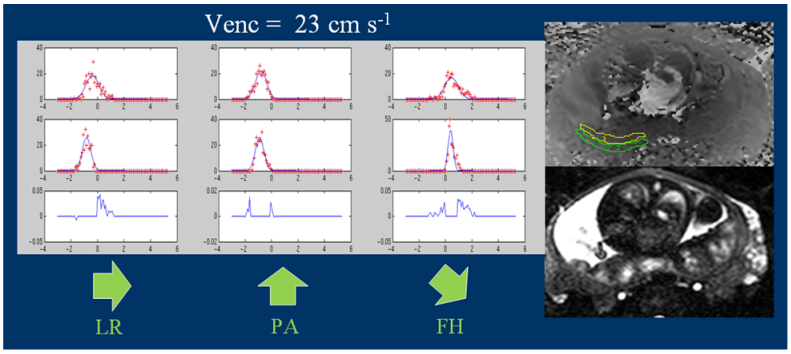

Figure 2: Diabetic subject (35 weeks) showing the velocity encoded phase and magnitude image with basal plate (green) and placental (yellow) ROIs indicated. Corresponding histograms of phase data (directions indicated by solid arrows below) for basal plate (top row) and placental ROIs (middle row) and difference histogram (bottom row). Note shifting and broadening of basal plate histogram.

Results: Figure 1 shows typical flow maps and Figure 2 shows histograms of regions in the basal plate and placenta. High flow regions were concentrated in the basal plate and spiral arteries, although some coherent flow was observed in the placenta in a few patients (Figure 3). Flow velocities of up to 20 cm s^{-1} were observed in some pixels. Considering the difference histograms, over all subjects the fractions of voxels in the basal plate ROI showing significant coherent flow were 32 % and 3 % in the FH and HF directions, and for posterior placentas, 0 % and 8 % in the AP and PA directions and 5 % and 16 % in the LR and RL directions.

Discussion: This is the first report of flow velocity measurements in the human placenta using MRI. High flow can be identified in the myometrium, basal plate and chorionic plate. There are also areas of high flow in the placenta. Future work will aim at providing a robust method of analysing the flow histograms to allow systematic comparison between subjects. This technique may provide additional useful information about fluid mechanics of the placenta.

References: [1] S.T.Franics et al, (1995), Lancet **351**, 1397-1399; [2] R.J. Moore. (2000), Placenta, **21** 726-732. **FUNDED BY DIABETES UK.**

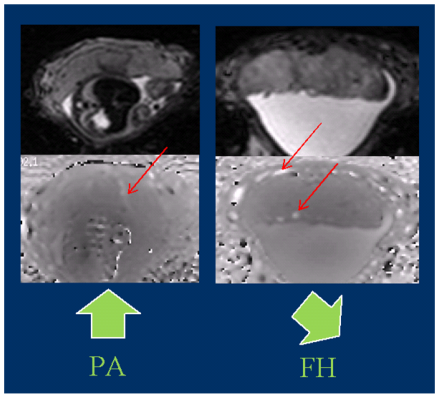

Figure 3: Red arrows show high flow regions in the placenta (left) and the basal plate and chorionic plate (right). Both subjects at 24 weeks.