Intravoxel Incoherent Motion Diffusion-weighted MR Imaging of the Placenta: Evaluation of Perfusion Changes in the Supine and Left Lateral Decubitus Positions

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Target Audience – This work is relevant to investigators surveying clinical applications of intravoxel incoherent motion (IVIM) and noncontrast MRI perfusion techniques. It is also relevant to researchers interested in studies of placental perfusion.

Purpose – Clinical evaluation of placental perfusion is limited by the contraindication of contrast agents with MRI and the inability to evaluate the entire placenta by ultrasound. Emerging research highlights the use of IVIM as a noncontrast marker of perfusion in organs [1]. IVIM is a diffusion-weighted imaging (DWI) technique that uses multiple different b values to separate out the molecular diffusion of water and microcirculation of blood in the capillary network [2]. Although a prior study has briefly examined the technique in evaluating placental perfusion, no prior studies have evaluated whether IVIM can assess for changes in perfusion in the same subject [3]. During pregnancy, the enlarged uterus compresses the aorta in the supine position, thereby decreasing blood flow to the uterus [4]. This hemodynamic relationship improves in the left lateral decubitus (LLD) position, which decreases the compression on the aorta. *In this pilot work, we hypothesize that IVIM can appropriately differentiate perfusion fractions between higher flow (LLD) and lower flow (supine) positions in the same subject.*

Methods – ***Cohort:*** 7 gravid females (mean gestational age of pregnancy: 29 5/7 weeks, range: 25 to 34 weeks) who were referred for clinical evaluation of a fetal abnormality seen on ultrasound participated. ***Imaging*:** Patients were initially scanned in the supine or LLD positions based on comfort and later switched positions. MRIs were performed on a Philips whole-body 1.5T system (Achieva R3.2) using a 16-channel torso array. A T2 single shot fast spin echo sequence (SSFSE) was utilized for anatomic localization of the placenta. Setup for the SSFSE sequence was axial acquisition, TR=12500ms, TE=120ms, 1.3 x 1.6 mm in-plane resolution, 7 mm slice thickness. Scan time was ~40 seconds for 40 slices. DWI was acquired by using a single-shot EPI sequence covering the same anatomical volume as the T2 SSFSE scan. The parameters of the sequence were involved TR=2995ms, TE=58ms, Spectral Pre-saturation with Inversion Recovery fat suppression, 2.5 x 2.5 mm in-plane resolution, 7mm slice thickness, 14 b-values with b={0, 2, 4, 6, 12, 15, 22, 30, 50, 75, 100, 200, 400, 600 s/mm^2} and SENSE (A/P) × 2. Scan time was ~4 minutes for 25 slices. ***Analysis*:** Post-processing was performed using the Philips Relax Maps Tool through the Interactive Data Language Virtual Machine based on the IVIM model $S/S_0 = (1–ƒ)\ e^{-bD} + ƒe\ –b(D+D^*)$, where the b-value represents the strength of the diffusion weighting, D is the diffusion constant, D* is the pseudo diffusion coefficient, and ƒ is the perfusion fraction (PF). Slice selection and region-of-interests (ROIs) through the placenta were drawn independently by a pediatric radiologist. Three ROIs of the upper, mid, and lower placenta were measured to generate PFs, and a mean PF was calculated. To control for differences in diffusion related to positioning rather than perfusion, ROIs were also drawn over the left erector spinae muscle at the same level.

Results – Baseline characteristics of the study cohort are listed in Table 1. Fig. 1 shows axial DWI and perfusion fraction maps of the mid placenta in the supine and LLD positions with a region of interest shown around the mid region of the placenta. In all seven subjects, mean PF was significantly higher in the LLD position compared with the supine position. Fig. 2 whisker plots show statistically higher PF in the left lateral decubitus position compared with the supine position (35% vs 25%, $P < 0.001$), with no significant perfusion fraction difference in the erector spinae muscle at the same level (12% vs 12%, $p = 0.56$). There were no significant correlations between placenta PF and maternal age, maternal weight, gestational age, placental volume, and estimated fetal weight, although correlations between placenta PF and gestational age and placental volume were highest.

Discussion – We evaluated the feasibility of IVIM to measure differences in PF in the placenta based on positioning in a pilot cohort. To our knowledge, such assessment has not been previously reported in the literature. The results suggest that placental PF measurements are significantly different based on positioning, with higher PFs seen in the left lateral decubitus position, which is expected because of the decreased mass effect on the vascular structures.

Conclusion – This work offers evidence that IVIM is a feasible non-contrast quantitative MRI technique that can evaluate differences in placenta perfusion in the same subject. Future studies may further expand the use of IVIM as an objective biomarker for placental perfusion and its relationship to fetal growth and development, which would be particularly useful in the setting of intrauterine growth restriction.

Table 1: Subject Characteristics

	Age (yr)	Weight (kg)	Gest. Age at MRI	Placenta Volume (cm³)	Est. Fetal Weight by US (g)
1	18.4	58.2	29 1/7	633	1015
2	26.4	60.1	25 3/7	498	559
3	31.7	74.0	34	923	1421
4	31.2	78.0	30 3/7	544	1324
5	31.9	66.0	29	643	968
6	30.8	85.5	34 5/7	1037	1921
7	21.5	58.4	25 1/7	318	456

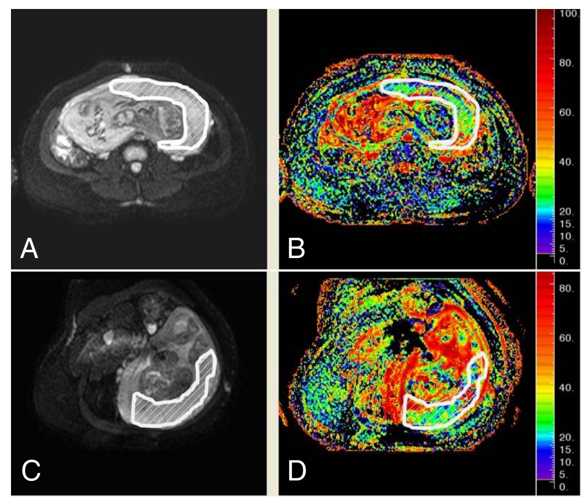

Fig. 1 Axial DWI of the mid placenta (A) and PF map (B) in the supine position and axial DWI of the of the mid placenta (C) and PF map (D) in the LLD position. ROIs drawn over the placenta show increased PF in the LLD position (38%) versus the supine position (24%).

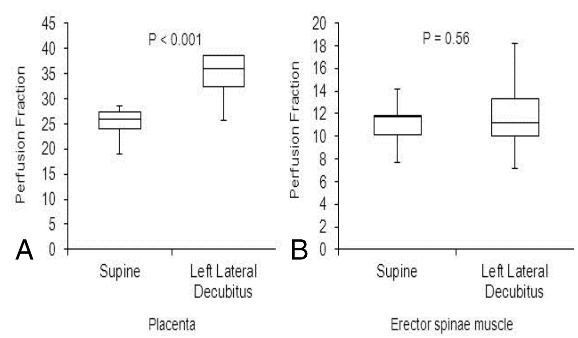

Fig. 2 Whisker plot of placental PF in the supine and LLD positions shows significant increase in the LLD position (A). Whisker plot of erector spinae muscle PF in the supine and LLD positions shows no significant difference (B).

[1] Le Bihan. Radiology 2008;249:748-752. [2] Le Bihan et al. Radiology 1988;168:497-505. [3] Derwig, et al. MRI 2012;30:323-329. [4] Kauppila, et al. Obstet Gynecol 1980;55:203-205.