

# Placental Insufficiency Investigated with Multi-compartment Placental MRI

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## Synopsis

Efficient exchange of oxygen and nutrients across the placenta is vital for a normally grown fetus. When remodelling of maternal arteries does not occur in early pregnancy the result is placental insufficiency, and fetal growth restriction. Previous studies have shown differences in T2 relaxometry and IVIM between normal and FGR placentae. Here we use a combined T2R and IVIM signal model that separates signals from fetal and maternal blood pools over the whole placental volume. We show difference in T2R, ADC, and maternal perfusion fraction, findings in keeping with previous literature and the pathophysiology of placental insufficiency.

## Introduction

Efficient exchange of oxygen and nutrients across the placenta is vital for a normally grown fetus. One third of stillbirths are caused by placental insufficiency<sup>1</sup>, but the vascular properties of the placenta cannot be accurately measured in utero and remain poorly understood. Trophoblast (placental cell) remodelling of the maternal spiral arteries in the decidua normally results in a high volume low resistance maternal placental circulation<sup>2</sup>. This remodelling is inadequate in placental insufficiency<sup>4</sup> and will lead to fetal growth restriction (FGR). There is no treatment that can improve placental perfusion, thus the only intervention is careful planning of early delivery, balancing the risk of fetal demise due to placental failure against the risks of severe prematurity of birth. Previous placental MRI studies of T2 relaxometry (T2R) and Intravoxel incoherent motion (IVIM)<sup>4,5</sup>, have shown differences between normal and FGR placentae<sup>6,7</sup>. Here we use a combined T2R and IVIM signal model<sup>10</sup> that separates signals from fetal ( $f^*$ ) and maternal ( $v$ ) blood pools over the whole placental volume, and use this to investigate fetal and maternal placental perfusion in normal singleton pregnancies and FGR.

## Methods

Four women in mid-pregnancy (28+4 to 34+0 gestational weeks) with normally grown fetuses, and three with severe FGR (25+4 to 28+5 gestational weeks) consented for fetal MRI. Obstetric ultrasound confirmed normal fetal growth and fetal and maternal Doppler studies in the control group, all of whom delivered a normally grown baby at term. Ultrasound in the FGR group found estimated fetal weight less than the 1st centile in all cases, with increased resistance in the uterine artery Doppler's. FGR1 had normal umbilical artery Doppler's, and delivered at full term whilst FGR2 and FGR3 had abnormal umbilical artery Doppler's and delivered at 29+5 and 28+6 gestational weeks respectively. Imaging was performed on 1.5T Siemens Symphony, taking 41 measurements grouped across 7 b-values and 10 echo times (FIGURE 1). We adapt the DECIDE model<sup>10</sup> to take into account typical T2 values from recent literature<sup>11</sup> and assign a fetal T2 of 190ms and a maternal T2 of 230ms based upon estimated oxygen saturations<sup>11,12</sup>.

## Results

Figure 2 shows example parametric maps for two cases of FGR and two control pregnancies. T2 and ADC maps are visually quite similar between control and pathological placenta, whilst volume fractions of fetal ( $f^*$ ) and maternal ( $v$ ) perfusion are visibly reduced.

Figure 3 shows parametric histograms over the whole placenta for four imaging parameters. ADC distributions in column two are observed to be different between control and FGR placentae with mean ADC  $0.0018(0.0002)\text{mm}^2\text{s}^{-1}$  for control and  $0.0014(0.0004)\text{mm}^2\text{s}^{-1}$  for FGR2/3 (95% CI:  $[-0.0004, -0.0004]\text{mm}^2\text{s}^{-1}$ ). Interestingly the FGR case that delivered at term has an ADC closer to the appearance of the control placentae ( $0.0017(0.0002)\text{mm}^2\text{s}^{-1}$ ), motivating its removal from the reported FGR statistics. T2 was reduced in FGR (143.7(59)ms normal vs 119.7(68)ms FGR2/3 (95% CI:  $[-24.9, 21.6]\text{ms}$ )). Fetal perfusion fraction ( $f^*$ ) was similar (0.14(0.11) control vs 0.11(0.12) FGR2/3 (95% CI:  $[-0.034, -0.028]$ )), whilst the maternal perfusion fraction ( $v$ ) was reduced in FGR (0.24(0.16) control vs 0.17(0.17) FGR2/3 (95% CI:  $[-0.075, -0.065]$ )).

## Conclusion

Fetal Growth Restriction shows marked differences from control imaging data on multi-parametric MRI. Average T2 and ADC values are shown to be lower, replicating previous results in FGR, whilst the interpretation of these results as vascular volume fractions allows the observation that FGR cases have reduced maternal perfusion fraction ( $v$ ), in keeping with the known pathophysiology of placental insufficiency.

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## Figures

		Echo Time (ms)										
		0	96	81	90	120	150	180	210	240	270	300
b-value (s.mm <sup>-2</sup> )	50	96			90	120	150	180				
	100	96										
	150	96										
	200	96	81	90	120	150	180	210	240			
	400	96										
	600	96										

\*41 measurements total (images at 96ms TE acquired 3 times).

FIGURE 1: Image acquisition parameters for DECIDE. Images at 96ms TE constitute an IVIM-like acquisition and are acquired three times across slice-phase-read directions. Total imaging time was 20 minutes, which was well tolerated by all subjects. We used a non-rigid registration routine and manual segmentation of the whole placenta in all slices. The DECIDE multi-compartment model was then fitted to the data.

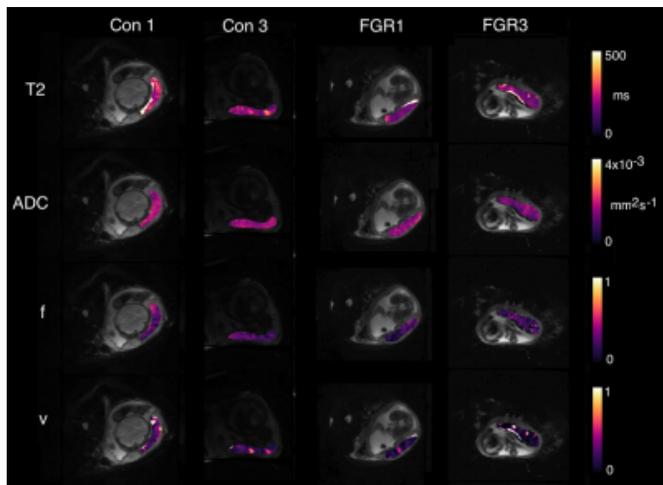


Figure 2: Example parametric maps for T2 (top row), ADC (second row), f\* (third row) and v (fourth row) for an example slice for two control placentae and two FGR placentae. Signal of f\* and v are noticeably reduced in FGR compared to control.

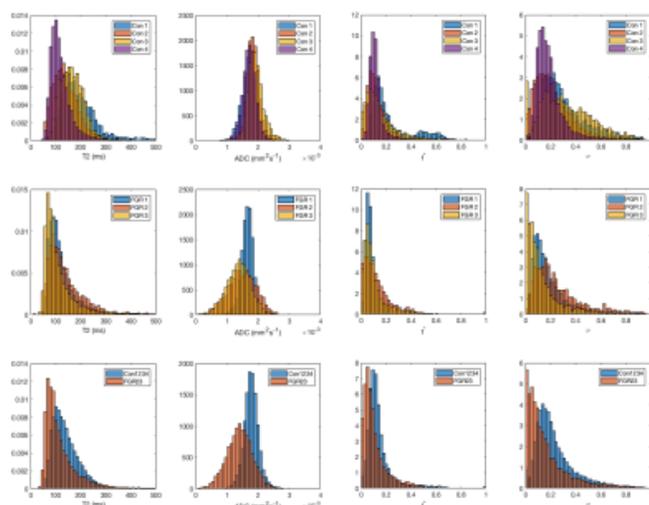


Figure 3: Parametric histograms for each whole placenta data for top row: Controls: T2, ADC, f\*, v. Middle row: FGR cases: T2, ADC, f\*, v. Bottom row all control data grouped and FGR 2 and 3 grouped for T2, ADC, f\* and v. FGR 1 delivered a term and is not included in this row of histograms.

