A Quantitative Tool for the Study of Fetal Adipose Tissue Development in Utero: 3D Water-Fat MRI
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Purpose: Fetal adipose tissue development is difficult to study in utero, however ultrasound and magnetic resonance imaging (MRI) may be suitable methods as they do not deliver ionizing radiation and can be used safely during pregnancy. Previous MRI and ultrasound studies have measured the fetal adipose tissue volume and revealed relationships with maternal health (e.g., Gestational diabetes) and pregnancy outcomes (e.g., Fetal growth restriction, macrosomia). These studies have only examined the volume of the adipose tissue, and have not measured the lipid content of the adipocytes. 3D water-fat MRI provides a fat fraction (FF = fat/(water+fat)), which quantifies the proportion of MRI signal received from lipid. Since pre-adipocytes are primarily water-based cells and mature adipocytes mostly consist of a large lipid-filled vesicle resulting in a fat fraction near 90% in adult white adipose tissue, it is possible to assess the maturity of the adipose tissue with MRI.

Hypothesis: 3D water-fat MRI provides highly sensitive and specific measurements of fat fraction which is a surrogate measure of adipose maturity.

Methods: Women with singleton pregnancies in their second or third trimester underwent a fetal MRI in a wide-bore (70cm diameter) 1.5T MRI (GE Optima 450w). T1-, T2-weighted, fat- and water-only images oriented axial to the fetus were obtained. From the reconstruction of the fat and water images, fat signal fraction maps were also obtained. The fetal subcutaneous adipose tissue (FSAT) was segmented along the trunk, and the fat signal fraction (FSF) and lipid volume were measured within this tissue. Estimated fetal weight percentiles were calculated using MRI measured fetal volumes, a fetal density formula, and the Hadlock growth standards. Correlations were assessed between our fat measurements and maternal pre-pregnancy BMI, estimated fetal weight percentiles, and gestational age.

Results: 24 women were recruited to the study (BMI 19.2 – 52.5 kg/m²) with gestational ages between 28 and 38 weeks. One participant was not able to complete the MRI exam, and 2 FF images sets were corrupted by motion and could not be analyzed. No correlation was observed between maternal pre-pregnancy BMI and FSF or lipid volume (R²=0.03 and R²=0.05 respectively), or between EFW percentile and FSF or lipid volume (R²=0.07 and R²=0.1 respectively). A significant positive correlation was observed between gestational age and FSF (R²=0.42, P=0.002), and between gestational age and lipid volume (R²=0.40, P=0.002).

Discussion and Conclusion: During the gestational age window we examined, the positive correlation between gestational age and FSF indicates that the FSAT is depositing lipid within adipocytes, and that it has not yet reached full white adipose tissue maturity (FF=90% at maturity). This appears to be a key time for adipose tissue development during which adipocytes are rapidly filling with lipid. In conclusion, 3D water-fat MRI can be used to non-invasively study the development of fetal adipose tissue in mid to late gestation.