The Effect of Maternal Diabetes on Fetal Adiposity

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Introduction: Pregnancy among women with pre-existing diabetes is associated with poor maternal and fetal outcomes[1]. Macrosomia (large fetus with birth weight > 90th percentile) is a common complication associated with diabetic pregnancies[2] and infants of woman with diabetes are at higher risk of becoming obese and developing Type 2 diabetes at a young age[3]. The ability to measure fetal fat would be an invaluable tool in predicting adverse neonatal outcomes, managing compromised pregnancies and investigating the relationship between maternal diabetes and fetal development. This abstract describes the protocol and findings of fetal fat in normal and diabetic pregnancy. We have considered two approaches: measuring fetal fat across the abdomen and measuring fetal fat across the whole body. **Aim:** To study the fetal fat distribution in normal and diabetic pregnancies.

Methods: Scanning: Following ethics committee approval, 24 healthy pregnant women from Queen's Medical Centre Nottingham were recruited and gave informed consent to participate in the study. Pregnant women underwent two scans at 24–26 weeks and 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 lay on their right side in the decubitus position to avoid vena cava compression. All these scans were conducted with a specific absorption rate of < 2.0 W kg^{-1}. Two protocols were investigated: the *TOTAL* sequence was a breath-held, multi-slice, water suppressed fast field echo (FFE) sequence acquiring 12 transverse slices encompassing the whole fetus in 12.4 seconds (TR = 147 ms, TE = 4.6 ms, 1.88×1.86×6.00 mm^3, slice gap = 20 mm and FOV = 402 mm). An *ABDO* sequence was also acquired, focusing on 5 slices over the fetal abdomen. Analysis: The images clearly show fetal and maternal fat (and little else) but the fetal fat distribution was too complex to manually segment. Instead a semi-automated analysis approach was developed based on image thresholding. First, the observer drew a freehand mask (GIMP 2.2.13) around the fetus to discard maternal fat. The mask and images were then loaded into Matlab (R2010a) to compute the intensity histogram within the masked region. These histograms were often bimodal with one peak corresponding to background noise and a second corresponding to fat voxels. We used the equation in Box 1 to estimate fetal fat volume, excluding noise and correcting somewhat for partial volume effects; this has previously proved to give reliable estimates[4]. Three observers also assessed whether the images showed evidence of intra-abdominal (visceral) fat (scored 2: definite; 1: possible; 0: none).

Results: No fetal fat was observed at 24–26 weeks and so no attempt was made to measure it. The *ABDO* protocol was prone to inevitable errors in correctly positioning the acquisition volume. This problem was overcome using the *TOTAL* protocol, which covered the whole fetus. Nonetheless the *ABDO* protocol was used to assist in the subjective assessment of intra-abdominal fat. Figure 3 shows that the total fetal fat volume measured in diabetic pregnancies is significantly greater than in normal pregnancies ($p = 0.016$). Figure 4 shows slices from a control and a diabetic data set. There is also evidence of increased intra-abdominal fetal fat in diabetic pregnancies. The subjective intra-abdominal fat score was 1.3 for diabetics and 0.4 for controls.

Discussion: We have shown that fetal fat volume is increased in the fetuses of diabetic mothers; we will now compare this to total fetal volume. It is not feasible to image every slice in a reasonable imaging time, so the fetal fat must be measured from a set of images sampling the fetus. It was found that the most reliable approach was to acquire images across the whole fetus using the *TOTAL* protocol. Unfortunately this requires the mother to breathhold for a long time, takes longer to analyse the data, and can lose image quality near the ends of the coil and shim volume.

References: [1] Pregnancy in women with Type 1 and Type 2 diabetes. Confidential Enquiry into Maternal and Child Health Report. 2005. [2] M.W. Gillman et al. (2003), PEDIATRICS **111(3)** e221-e226. [3] S.P. Chauhan et al. (2005), Am J Obstet Gynecol **193** 332-346. [4] D. Anblagan, Proc ISMRM 19 (2010) 5910. **FUNDED BY DIABETES UK.**

Box 1: Find the position of the maximum of the noise peak (hmax, Figure 2). Calculated scaling function:

$$S_j = (1 - \exp(-k(j - 2hmax)/(Nbins - 2hmax)))$$

where j = bin position, Nbins = total number of bins and k = 6 is a constant which ensures full scaling at Nbin.

Estimate fat volume (EFV) as:

$$EFV = X \times Y \times (Z+G).\sum_j^{Nbins} H_j \times S_j$$

where H_j = histogram, X,Y,Z = voxel dimensions, G = slice gap.

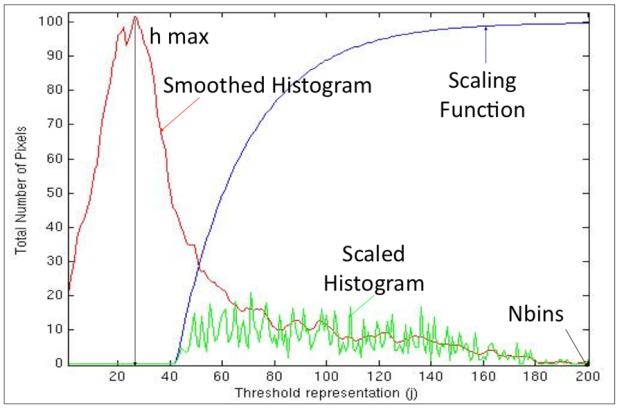

Figure 2: Histogram of the pixel intensity to determine the threshold separating fat and background noise signals.

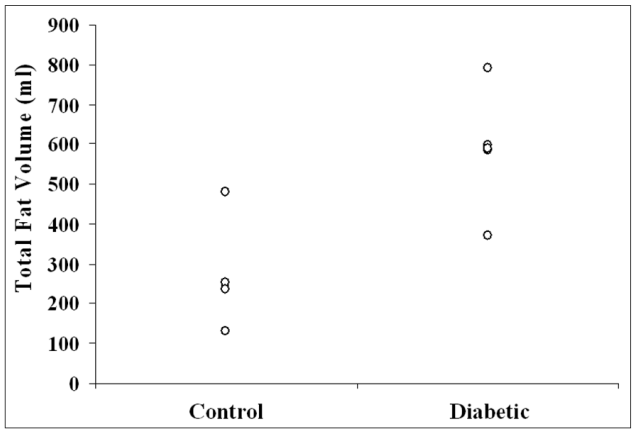

Figure 3: Comparison of *TOTAL* fetal fat volume in normal and diabetic pregnancies in late GA (34–36 weeks)

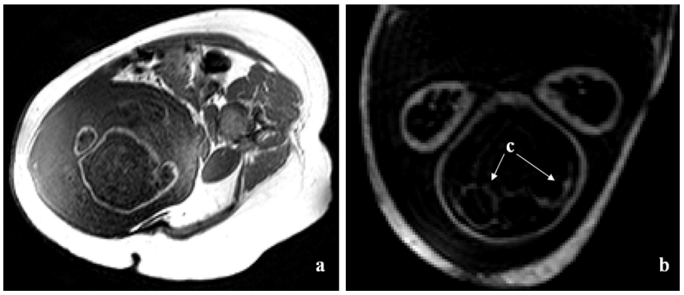

Figure 4: Fat only image of a transverse plane through the fetal thorax: (a) Control (b) Diabetic (c) Intra-abdominal fat visible around kidney