Automated Volumetric Fat Quantification of Adipose Tissue in Mice

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Target Audience: Researchers interested in adipose quantification in rodents.

Introduction: Intra-Abdominal Adipose Tissue (IAAT) is an indicator of disease onset, specifically long-term development of type-2 diabetes and cardiovascular disease[1]. Recently, a method for automated quantification of adipose distribution in human water-fat separated magnetic resonance (MR) images was validated[2]. Research using animals allows studies with shorter time scales, invasive procedures, and reduces the difficulty of longitudinal research. We propose an adaptation of the human method to quantify Total Adipose Tissue (TAT), Subcutaneous Adipose Tissue (SAT), and IAAT in mouse MR images.

Methods: *In vivo* data were obtained from 5 mice (3 obese mice, 2 lean mice) that were anesthetized with isoflurane under a protocol approved by the institution's Animal Use Subcommittee. Coronal images were collected using an investigational version of IDEAL (# echoes = 6, Echo Spacing = 1.05 ms, 0.7 mm slice thickness, FOV = 11 cm x 6.6 cm x 3 cm, Scan Time = 15 min, matrix = 148x148x58, NEX = 10) using a single channel proton coil in a GE 3.0 T MR750 (GE Healthcare, Waukesha, WI). Images were reformatted to the transverse plane and a subset of 10 slices located between the diaphragm and pelvis were analyzed for fat distribution. Our automated method uses fat fraction values to identify adipose and lean muscle tissue. Then, using the water image, a 3D surface is fit over the external muscles in polar coordinates to segment SAT from internal adipose tissue. Then IAAT is determined to be the remaining adipose tissue inside the SAT. The human method was adapted by changing the fat fraction thresholds ranges for lean muscle and adipose tissue to account for prevalent partial volumes of water-fat boundaries in mice. This threshold is manually adjusted based on the apparent fat fraction of the muscle tissue layer. The volumes of TAT, IAAT and SAT were calculated from the segmented images and were compared to manual segmentations[3] (Figure 1).

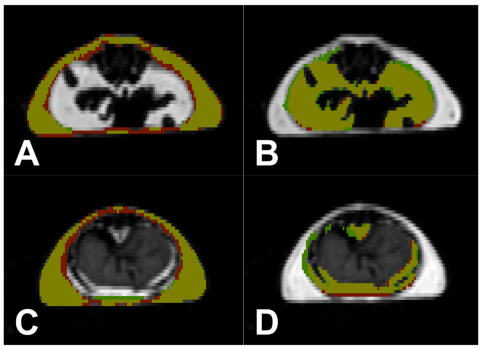

Figure 1. Example segmentations of SAT (A,C) and IAAT (B,D) from two slices in a mouse. A and B are a slice with high internal fat, while C and D are a slice with low internal fat including the liver. Red pixels were selected by the manual segmentation, green pixels were selected by the automated segmentation, and yellow pixels were selected by both methods.

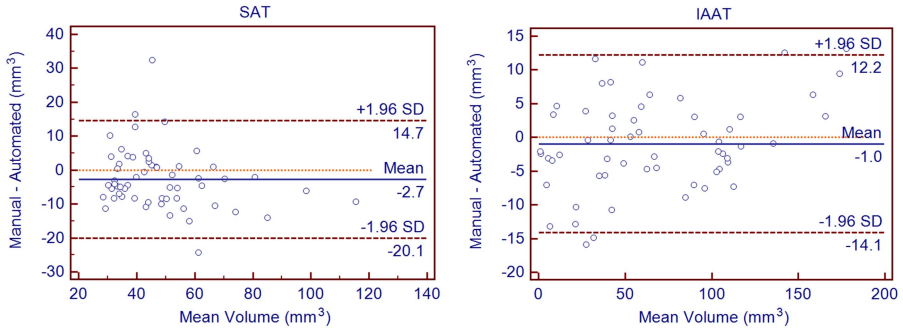

Figure 2. Bland-Altman plots of Subcutaneous Adipose Tissue (SAT) and Intra-Abdominal Adipose Tissue (IAAT). The solid line shows the mean measurement difference between manual and automated segmentations, while the long lines show the 95% confidence interval.

Results: Manual segmentation required 480 s/slice while automated segmentation required only 4 s/slice. Average TAT volume per slice for the mice was 125.7 mm^3. Manual and automated segmentation results showed good agreement with no substantial bias (Figure 2). The mean absolute difference between the manual and automated segmentation was (5.2 ± 3.6) mm^3 for IAAT and (6.7 ± 4.7) mm^3 for SAT.

Discussion: The automated technique was over 100x faster than manual segmentation, while requiring minimal interaction. The difference between automatically and manually segmented adipose compartment volumes is small relative to the total volume (7%). In-plane resolutions for these images were 0.7 mm, which is much larger than most segmentation techniques have displayed, demonstrating the ability of this method to accurately segment relatively low resolution images. The short time for segmentation and manageable imaging time makes use of this technique desirable for analysis of fat in large data sets. Future research will measure the reproducibility of this algorithm.

Conclusions: We have validated a method for rapid, automated fat segmentation that produces reliable and accurate quantification of adipose distributions in mice.

References: [1] Sam S *et al*., Relation of Abdominal Fat Depots to Systemic Markers of Inflammation in Type 2 Diabetes, Diabetes Care. 2009 May; 32(5): 932–937 [2] Addeman B *et al*., Validation of Volumetric and Single Slice MRI Adipose Analysis using a novel Fully Automated Segmentation method, JMRI, 2013 (In Press) [3] Alabousi A, Al-Attar S, Joy TR, Hegele RA, McKenzie CA, Evaluation of adipose tissue volume quantification with IDEAL fat-water separation, J Magn Reson Imaging;34(2):474-479.