Volumetric Fat Quantification of Intra-Abdominal Adipose Tissue from a Single Breath Hold Acquisition

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Introduction: The regional distribution of adipose tissue is of great clinical importance as Intra-Abdominal Adipose Tissue (IAAT) is associated with the long-term development of type 2 diabetes and cardiovascular disease [1,2]. Current quantification techniques use a single transverse slice located at the L2-L5 region for use with manual segmentation. However, large variations in individual internal fat content cannot be predicted from single-slice sampling strategies [3]. We propose a single-scan imaging technique covering the entire intra-abdominal cavity using a novel rapid automated segmentation technique to quantify Total Adipose Tissue (TAT), Subcutaneous Adipose Tissue (SAT), and IAAT.

Methods: Following REB approval and obtaining informed consent, *in vivo* data were obtained from 3 healthy volunteers. Transverse slices were collected extending from the diaphragm to the pelvic floor using a parallel MRI accelerated IDEAL-IQ pulse sequence on a GE 3.0 T MR750 (GE Healthcare, Waukesha, WI). Extra slices were collected on the superior and inferior ends and discarded since the edge slices in each large volume had diminished image quality. A 32-channel torso coil array (Neo Coil, Pewaukee, WI, USA) was used with the following scan parameters: # echoes = 6, Echo Train Length = 3, Flip Angle = 3°, FOV = 48x32 cm, matrix = 148x148x120 zero-padded to 256x256x120, 4 mm slice thickness, NEX=0.75, Net Acceleration Factor = 3.3, Scan time = 24-26 s. The Phase FOV, number of slices, and slice thickness were adjusted as needed to keep the scan time within a comfortable inspiratory breath-hold. In each patient the centre 78-88 slices were sufficient to cover the diaphragm to pelvic floor region. One of the volunteers was scanned an additional 2 times on a different day for reproducibility. The volunteer was removed from the table and re-landmarked between scans. Each of the slices was segmented manually using the method of Alabousi *et al.*[4], and using a novel in-house automated method which uses fat fraction values to locate adipose tissue, and water fraction values to locate the distal water tissue layer which lines the inside of the SAT. SAT is then recognized as adipose tissue distal to the water layer, and IAAT as the adipose tissue proximal to the water layer. Volumes of SAT and IAAT for each volunteer were calculated for both manual and automated methods.

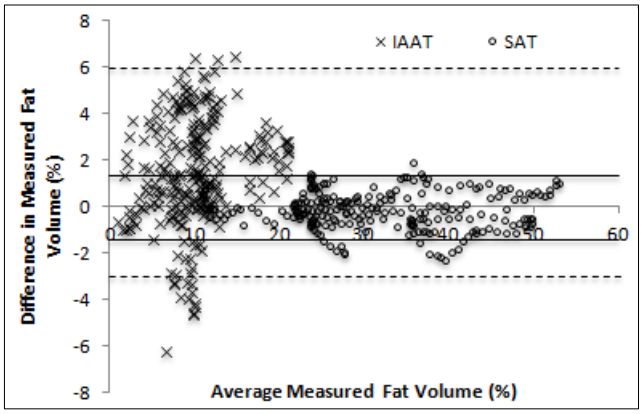

Figure 1 – Bland Altman plot comparing manual vs. automated segmentation of SAT and IAAT for each slice. 95% confidence interval lines are shown for SAT (solid) and IAAT (dashed). Difference in IAAT shows a positive bias caused by higher manual segmentation values (Mean = +1.4%).

Results: Automated segmentation agrees well with the manual segmentation technique. A Bland Altman plot (Figure 1) shows a bias toward higher fat volume measurements for manual segmentation of IAAT (Mean = +1.4%), but none for SAT (Mean = -0.13%). Automated segmentation was completed for each 78-88 slice volume within 2 minutes, less than 2 seconds per slice. Manual segmentation required at least 6 hours per volume. Fat volumes measured in reproducibility scans show excellent agreement varying less than 5% (< 120 cm^3 by volume) for each of TAT, SAT, and IAAT.

Discussion: Large variations in signal intensity were observed in each of the datasets due to acquisition with a 32-coil array. Fat fraction maps are not affected by this as the variations are seen equally in both the water and fat pixels. However, manual segmentation required lower thresholds be used to include all IAAT where fat intensities were lower due to the coil sensitivity pattern. As a result, more partial volume pixels were included in the manual technique, increasing the fat volume of IAAT measured. This was not a problem for SAT as coil sensitivities are more uniform in the SAT region. Segmentation of the gluteus-maximus, thigh, and calf regions has also been successful. In addition to adipose, volumetric water tissue measurements can be calculated (Figure 2).

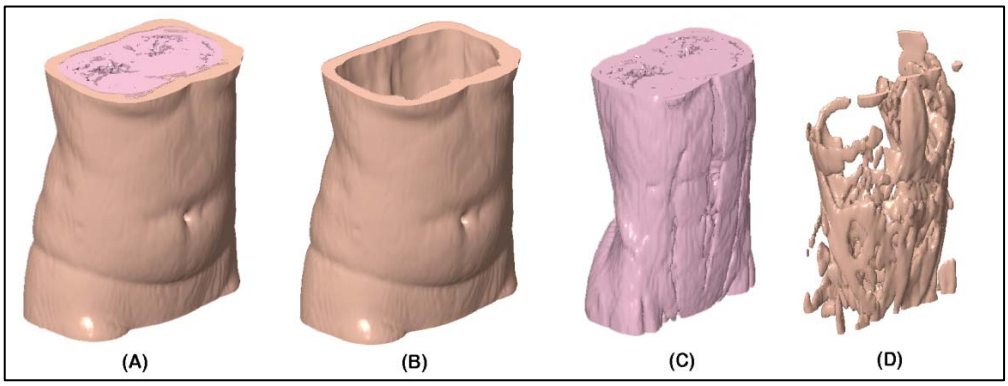

Figure 2 - Exploded view of 3D tissue segmentation. (A) SAT, IAAT, and Water Tissue. (B) SAT, (C) Water Tissue, (D) IAAT

Conclusions: We have demonstrated the ability to collect and accurately segment the entire intra-abdominal cavity within a single breath-hold scan. Volunteers were in-and-out of the scanner within 10 minutes, and volumetric analysis required less than 2 minutes. Results are very similar to those obtained by standard manual segmentation methods, but require no manual intervention, and can be calculated very rapidly.

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References: [1] Kuk JL, et al, Obesity 2006;14:336-341. [2] Despres JP, Lemieux I. Nature 2006;444:881-887. [3] Thomas E, et al. J appl Physiol 1998:85:1778-1785. [4] JMRI 2011;34:474-479.