Automatic Segmentation of Adipose Tissue Distribution in Childhood Obesity

A. Rajagopal[1], K. O'Brien[1], V. Schmithorst[1], M. Kalra[2], B. J. Dardzinski[1,3]

[1]Imaging Research Center, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, United States, [2]Division of Pulmonary Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, United States, [3]Radiology, University of Cincinnati College of Medicine, Cincinnati, OH, United States

Introduction:

The prevalence of childhood obesity (15-20%) is at epidemic proportions in the United States. Co-morbidities of obesity include cardiac risk factors, diabetes and sleep apnea (1). Children with severe obesity and sleep apnea may have to undergo weight loss surgery. Many of the complications are related to the accumulation of visceral fat. It has been indicated that the ratio of intra-abdominal to subcutaneous fat is related to these co-morbidities (2, 3). MR imaging of the abdomen provides accurate non-invasive measurements of pediatric visceral fat. As a part of a larger study in childhood obesity, our center has developed MR imaging techniques and methodology to calculate subcutaneous and intra abdominal adiposity. This study compares previous manual methods with an automated procedure (4).

Materials and Methods:

Axial T1 images (TR/TE = 500/14 msec, matrix of 256 x 160, total acquisition time of 2.5 min) of the abdomen from the lower end of the xiphoid process to the upper end of the iliac crest were acquired using a 1.5T GE LX MR system (GE Medical Systems, Milwaukee, WI) with the body RF coil. Forty two children (19 girls and 23 boys) in ages 13 – 21 years (mean age: 15.9 ± 2 y.o.) with obesity referred to the sleep apnea clinic were recruited for this MR study. The mean body mass index (BMI) was 44.1 ± 7.5 (range: 31.2 – 67.3) for these children.

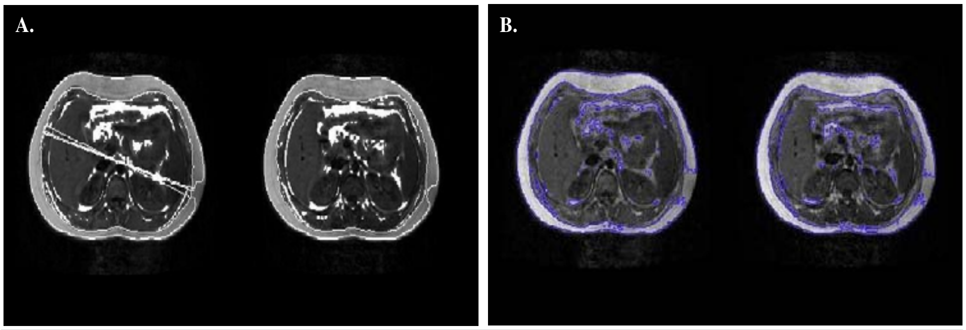

Figure 1: Two slices (#3 and #4) out of 16 and ROIs of TAT after segmentation **A.** Automatic (ROI in white) IAT = 0.84 l, SAT = 3.73 l, IAT/SAT = 22.5%, and **B.** Manual (ROI in blue) IAT = 0.46 l, SAT = 2.23 l, IAT/SAT = 20.6% for a 15 year old boy.

To segment the fat automatically, a program was written in CCHIPS (a semi-automated software program developed with IDL (RSI, Boulder, CO)) (5) to read the DICOM formatted images. The user was required to select the superior slice (SS), inferior slice (IS) and the umbilicus slice (US) to determine the various adipose tissue volumes: subcutaneous adipose tissue (SAT), intra-abdominal adipose tissue (IAT), and total adipose tissue (TAT). The volumes selected were the same for both the manual and automatic segmentation. All slices from SS to IS were segmented using a K-means clustering algorithm to determine the TAT. To obtain the SAT, a snake algorithm was applied to determine the external and internal boundaries. IAT was calculated as the difference between TAT and SAT. The ROIs for TAT obtained using both manual and auto segmentation is shown in Figure 1.

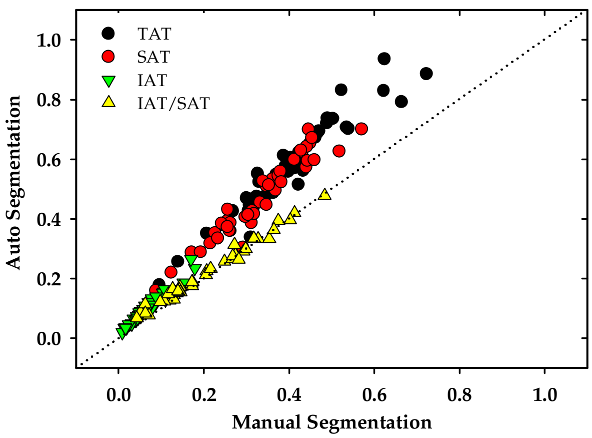

Figure 2: Correlation of automatic vs. manual segmentation of TAT, SAT, IAT and IAT/SAT ratio for 42 children.

Results and Discussion:

The mean SAT, TAT and IAT volume for all the slices in each patient obtained by manual segmentation was compared with the mean SAT, TAT and IAT obtained by auto segmentation. The mean values of TAT, SAT and IAT using the automated segmentation routine were higher by 30%. However the ratio (IAT/SAT) was only overestimated by 5%. The mean adipose tissue volumes were significantly correlated between the two methods (p-value < 0.005). The correlation values for TAT, SAT, IAT and IAT/SAT were 0.957, 0.958, 0.975 and 0.993 respectively with R^2 values of TAT: 0.916, SAT: 0.918, IAT: 0.951 -and IAT/SAT: 0.986 (Figure 2). The mean single umbilicus slice TAT, SAT, IAT and IAT/SAT were also highly correlated between the automatic and manual methods.

One disadvantage in the automatic segmentation routine is the failure of the snake routine when the signal intensity in the subcutaneous fat is very inhomogeneous (Fig 1A). The automatic routine also included bright voxels around the spine as adipose tissue; which were discarded by the experienced user during manual segmentation and can account for the overestimation of SAT and IAT in the automatic method.

Conclusion: The results demonstrate a high correlation between the adipose tissue measurements obtained by an automatic segmentation algorithm and those obtained by manual segmentation. The IAT/SAT ratio was only 5% higher with the automatic method but the analysis time was reduced 20 fold. This non-invasive technique can be used to monitor weight loss and adipose tissue distribution following bariatric surgery and other treatments for obesity.

References:

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