Establishment of a Novel Automated Approach for Quantification of Subcutaneous and Visceral Adipose Tissues: Correlates with Other Anthropometric Measurements and Cardiometabolic Risk Factors

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Introduction. Obesity, and in particular abdominal obesity, is a strong predictor of cardiovascular and metabolic diseases. Anthropometric measurements (body mass index BMI, waist-to-hip ratio WHR and waist circumference WC) and imaging techniques (computed tomography and ultrasound) have been used in clinical settings as proxies for abdominal obesity. Increasing number of studies have applied magnetic resonance imaging (MRI), a precise and non-invasive method, in quantifying abdominal fat and found associations between abdominal fat and various important health indicators [1]. However, manual and semi-automatic quantification of fat and distribution from MR images can be labor intensive, time consuming and subject to inter- and intra-observer variation. Existing automatic algorithms rely either on active contours segmentation [2], which can be sensitive to image noise and assumes sufficiently large intensity gradient within the connections between visceral (VAT) and subcutaneous (SAT) adipose tissues, or region growing [3], which has potential to overgrow through stronger tissue connections. We developed and evaluated an automatic segmentation tool based on graph cuts [5], which can successfully separate loosely connected tissues as well as stronger connections and validated the algorithm with cardiometabolic risk factors in a healthy elderly population.

Methods. Abdominal MR scans were obtained from 119 healthy elderly volunteers (age=65.5 ± 6 years). The MR data was acquired on a 3T system (Siemens Tim Trio) using the Dixon sequence (TR 4.20, TE 1.225, FA 10, voxel dimensions 2mm x 1.5mm x 2.5mm, 80 axial slices; slice thickness 2.5mm, 0.5mm interslice gap; sagittal scout Image plane at L3). Subjects held their breath for 16 s in each of two imaging runs to minimize motion artifacts. Anthropomorphic measures, such as height, weight and waist circumference were obtained and used to calculate BMI and WHR. The means of the two seated systolic (SBP) and diastolic (DBP) blood pressure measurements were used for analysis. Blood measurements, such as fasting triglycerides (TG), fasting plasma glucose, HDL- and LDL-cholesterol fractions and homocysteine were also available.

To extract adipose tissue we developed a fully automated algorithm based on histogram thresholding [4] followed by separation of VAT and SAT, implemented using a graph-cut minimization algorithm [5]. Weights were assigned to the graph based on image intensities and distances from the nearest tissue boundary. So defined, the weights will be small inside the connections between external fat and internal fat, favoring the subsequent cut through them. The fat volumes were quantified from the segmentation output. Independent samples t-test was used to examine the gender differences in VAT and SAT. Partial correlations, with gender as a covariate, were used to examine the associations between the abdominal adiposity tissues and anthropomorphic measures, and between the abdominal adiposity tissues and various cardiometabolic risk factors.

Results. An example of the results obtained with the automated segmentation algorithm is shown in Fig. 1. There was a significant gender effect on the abdominal adiposity, with females having more SAT (t = -5.73, $p<.001$) and males having more VAT (t = 4.94, $p<.001$). There were modest correlations between VAT, SAT and the various anthropomorphic measures (r ranged from 0.22 to 0.51, p<.05). Elevated VAT, and not SAT, was associated with the higher SBP (r = .22, $p<.05$), triglycerides (r = .30, $p<.01$), LDL-cholesterol (r = .21, $p<.05$) and homocysteine levels (r = 0.24, $p<.05$) and lower HDL-cholesterol (r = -.35, $p<.001$).

Conclusion. Preliminary findings provide external validity for our automated algorithm in estimating visceral and subcutaneous adipose tissues. Consistent with previous studies, women have more subcutaneous abdominal fat while men have more visceral abdominal fat [6]. Visceral, and not subcutaneous abdominal fat, is associated with the various risk factors for cardiometabolic diseases [7]. We conclude that this automated method of abdominal adiposity quantification and analysis is a sensitive and valid tool to be utilized in future epidemiological studies of abdominal adiposity and cardiovascular and metabolic health.
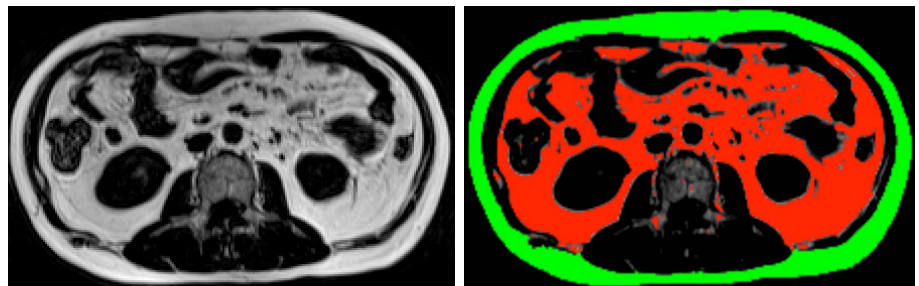

Figure 1. Results of the fat segmentation algorithm. VAT is highlighted in red, SAT in green.

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