An automatic segmentation and quantitation technique for abdominal fat from MR images of obese rats

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Introduction: Magnetic resonance spectroscopy (MRS) and magnetic resonance imaging (MRI) are shown to be effective methods for fat quantitation in both humans and animals. MRS measures the biochemical content including saturated and unsaturated lipids while the MRI helps to understand the spatial distribution of fat in different regions. Quantitation of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) fat is important to understand the overall obesity, insulin resistance, glucose intolerance, dyslipidemia, hypertension and coronary disease. Our study aims at exploring the influence of calorie restriction (CR) and exercise (Ex) on VAT and SAT. Manual quantitation is laborious, time-consuming, operator dependent and hence not feasible for large cohort studies. We propose an automatic hybrid method (graph and Fuzzy c-means based) for quantitation of SAT and VAT.

Methods: Transverse T2 weighted SE abdominal images (from L1 – L5 of the spine) were acquired on 7T Bruker Clinscan using volume transmit and surface receive coil from 35 animals at two time points (pre- and post-scans) during the study. Obesity was induced in rats by high fat diet (Research Diet, D12079B) from 5 to 18 weeks of age, all rats were divided into 5 groups (n = 7): control (Ctr), exercise once a day (Ex-1) and twice a day (Ex-2), and calorie restriction with -15% (CR-15) and -30% (CR-30) reduction in calorie intake. A slot of exercise was 30 (20m/min) using the treadmill (Columbus-1055SRM-E54 Exer-3/6-Dual). The interventions were performed for 4 weeks. The body weight was measured on weekdays and food intake was measured every day. Both scans (pre- and post-intervention) used the same protocol with an FOV of 65 X 65 mm, base resolution of 256 X 256. Segmentation of VAT and SAT was performed using hybrid (level-set [1, 2] and fuzzy c-means – FCM [3]) method (Fig.1) by an in-house developed MATLAB program. Firstly, the volume data was filtered using anisotropic filter to reduce the high frequency noise while preserving the edges. The edge strength was improved using edge enhancement. The initial mask or level set was derived from the binary image of the data for each slice. Level-set was allowed to expand and contract for localizing the boundary between SAT and VAT. FCM with different number of classes were performed on SAT and VAT regions respectively. The different FCM regions in SAT and VAT were merged based on the intensity and neighborhood relation (Fig. 2). Results of segmentation were checked for its consistency against the bio-chemical analysis.
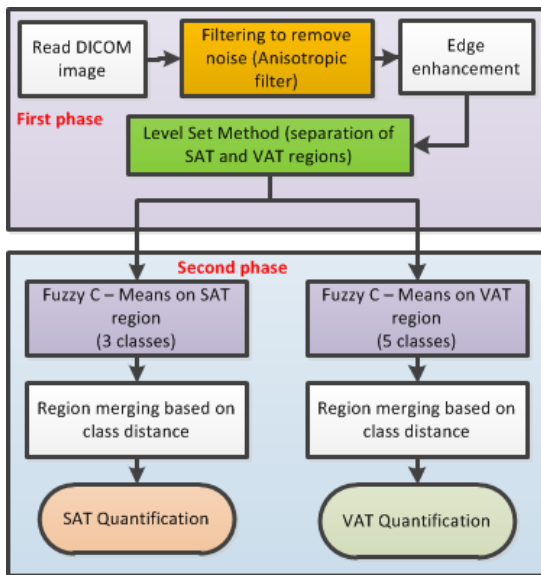

Fig. 1 Flowchart describing the steps involved in the proposed segmentation method
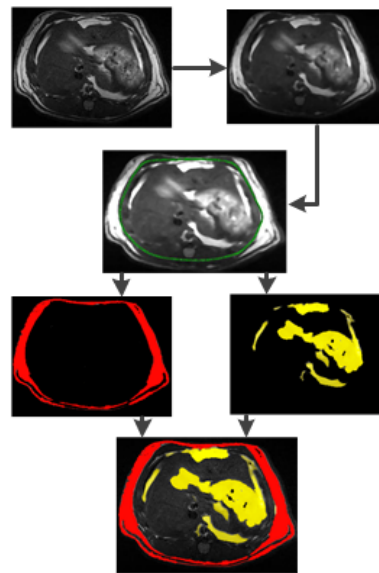

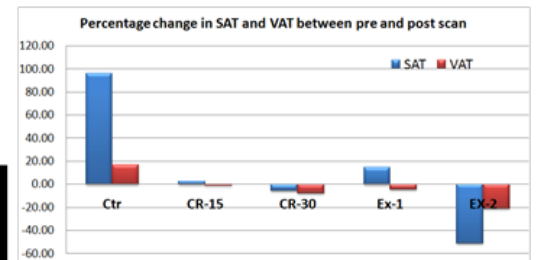Fig. 2 Results at different stages of the segmentation method

Fig. 3 Statistical analysis of the segmentation results

Results and Discussion: Figure 3 shows the percentage change in SAT and VAT between pre- and post-scan for different groups calculated using the proposed segmentation method. The increase in VAT and SAT was highest in the control group. Ex-1 showed increase of SAT and decrease in VAT; while for group Ex-2 both VAT and SAT decreased significantly. CR- 15 had increase in SAT and decrease in VAT while CR-30 showed decrease in both VAT and SAT. T-test was performed to analyze the significance of the changes. Decrease in VAT percentage was statistically significant ($p < 0.02$) among all the groups whereas for SAT decrease Ex-2 and CR-30 had significant results ($p < 0.03$). The segmentation results correlated with the spectroscopic and bio-chemical analysis. CR – 30 and Ex -2 had more significant results than CR – 15 and Ex-1 respectively.

Conclusions: MR based image analysis and segmentation is a useful technique to study the influence of exercise and calorie restriction on the obesity models. Our study showed that endurance exercise and calorie restriction reduces both SAT and VAT. The automated segmentation approach reduced the time needed to process each data and also avoids user interference. . The inter- and intra- variability is reduced due to the automation.

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