Improved unsupervised assessment of abdominal fat in MRI by automatic correction of intensity inhomogeneities

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Introduction: Assessment of the abdominal adipose tissue distribution has been recognized as a valuable diagnostic index in several chronic diseases, such as diabetes, hypertension, atherosclerosis, and cardiovascular disease. Magnetic resonance imaging (MRI) was demonstrated able to measure adipose tissue safely and accurately. Automatic post-processing methods may evaluate subcutaneous (SAT) and visceral fat (VAT) in robust and accurate way, exploiting a fuzzy clustering approach joined with active contours and histogram-based segmentation [1]. However, the results of the unsupervised analysis strongly depend from image quality, and in particular from the presence of image intensity inhomogeneities [2]. The problem becomes more important as the scanner field increases. In this study we propose to integrate an automatic correction procedure in the fuzzy clustering segmentation, in order to obtain a good quality of the unsupervised segmentation procedure also in presence of image intensity distortions.

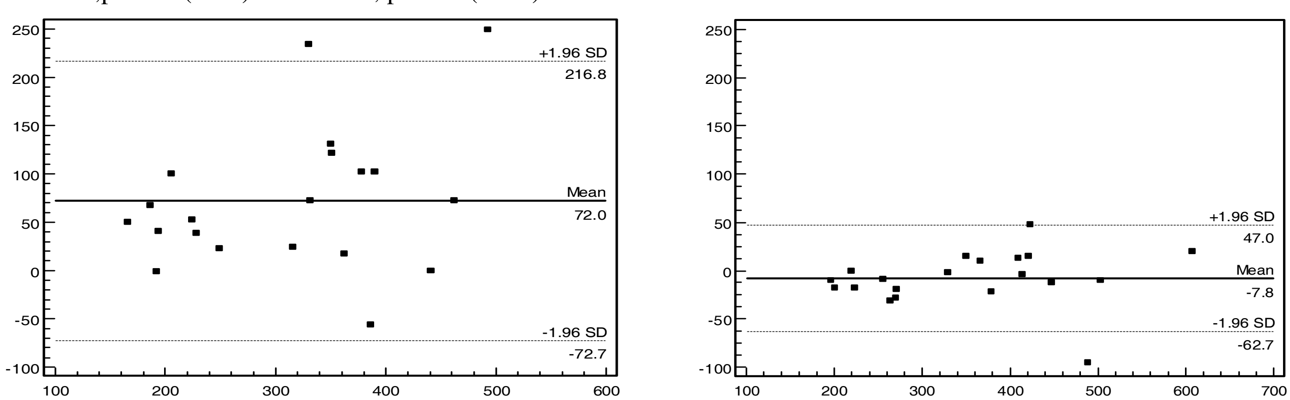
Materials and methods: Twenty obese and non-obese subjects underwent whole-abdomen MR imaging. Informed consent was obtained from all of them. Subjects were imaged on a 1.9 T Elscint Prestige scanner using a standard body coil with a spin lattice longitudinal relaxation time-weighted spin echo pulse sequence (TR=500 ms, TE=12 ms, image size 206x256, slice thickness 6 mm, gap 1.2 mm). One representative image for each scan corresponding to the umbilicus level was analyzed. All images are affected by relevant intensity distortions mainly due to field inhomogeneities.

All 20 images underwent to unsupervised segmentation of SAT and VAT using the validated HIPPO FAT tool [1,2]. The software defines three masks (background, fat, and non-fat tissues) using a fuzzy clustering segmentation. SAT is defined by means of active contour algorithm, while VAT is defined by automated analysis of the signal histogram in the visceral region.

Images were also processed by an improved version of the software, including automatic correction of intensity inhomogeneities. The correction was implemented extending the standard fuzzy clustering approach used in the HIPPO FAT. The developed algorithm models the intensity inhomogeneities as a gain field that causes image intensities to smoothly and slowly vary through the image space. The gain field iteratively adapts to the intensity inhomogeneities following the process of the fuzzy clustering algorithm [3]. Appropriate regularization terms are introduced in the objective function minimized by the fuzzy clustering algorithm to assure that the gain field will be spatially smooth and slowly varying.

In order to measure the effectiveness of the two methods, data acquired were compared to the ones obtained by manual analysis performed by a trained operator that was considered as the gold standard.

Results: The mean percentage error, evaluated respect to manual analysis, in SAT and VAT assessment by the standard HIPPO FAT tool was 21% and 16%, respectively. Correlation coefficient were r=0.77,p<0.01 (SAT) and r=0.92, p<0.01 (VAT). When correction for field inhomogeneities was applied, SAT and VAT percentage errors become 6% and 14 %,respectively. Correlation coefficients became r=0.97,p<0.01 (SAT) and r=0.92, p<0.01 (VAT).



The Bland and Altman plots for SAT evaluation by standard algorithm (left) and improved algorithm (right) vs. manual analysis are shown in figure.

Discussion: Correction of intensity distortions is important in SAT evaluation, while it is not significant in VAT measurement. This can be explained by the fact that distortions mainly affect peripheral regions of the scanner bore where SAT is placed, while VAT lies in the center of the scanner where distortions are minimal. Moreover, errors induced by intensity inhomogeneities become more relevant as the SAT value (and likely the patient size) increases. The developed correction procedure dramatically reduces the systematic error in SAT measurement, improving at the same time the confidence interval in the Bland and Altman analysis. Although a good correlation between unsupervised and manual analysis still exists when no correction is applied, the results of this study suggest that the compensation of signal inhomogeneities greatly improve the effectiveness of the automatic assessment of abdominal fat.

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