Software for fully automatic quantification of abdominal fat with manual correction option: evaluation in morbidly obese patients

Gregor Thörmer[1], Henriette Helene Bertram[1], Veronika Peter[2], Tatjana Schütz[2], Edward Shang[2], Matthias Blüher[3], Thomas Kahn[1], and Harald Busse[1]
[1]*Dept. of Diagnostic and Interventional Radiology, Leipzig University Hospital, Leipzig, Saxony, Germany,* [2]*Dept. of Visceral, Transplantation, Thoracic and Vascular Surgery, Section Bariatric Surgery, Leipzig University Hospital, Leipzig, Saxony, Germany,* [3]*Dept. of Endocrinology and Nephrology, Leipzig University Hospital, Leipzig, Saxony, Germany*

Introduction/Purpose

MRI is well suited for the selective depiction of fat and quantification of visceral and subcutaneous volumes of adipose tissue depots (VAT and SAT). Semiautomatic threshold-based and fully automated techniques can be used for rapid image segmentation [1], but any unsupervised analysis is prone to errors caused by anatomical variations and image artifacts, in particular for advanced stages of obesity [2]. Therefore, we have developed a user interface for the rapid inspection of automatically segmented fat areas and performed a preliminary data analysis on 20 morbidly obese patients.

Materials and Methods

A fully automated, three-stage analysis method to quantify total adipose tissue (TAT), SAT and VAT was implemented under Matlab (The Mathworks, Natick, MA). In short, the algorithm uses pixel clustering, region growing and active contours (snakes) to automatically identify the boundaries between background, SAT, and VAT in each image. Fat fraction images, calculated from double-echo raw data, are then presented in a graphical user interface (Fig. 1) featuring dedicated windows for an intuitive and rapid inspection of the segmentation results. Data sets, masks, and thresholds can be saved and restored for further processing and all quantitative VAT and SAT measures can be exported in standard spreadsheet formats. In a dedicated run-time Matlab environment (MCR), the software tool can be run on any standard PC.

The software was evaluated by processing the data of 20 morbidly obese patients. The results were compared to manual processing by two readers using SliceOMatic (Tomovision, Magog, Canada). Sixteen female and 4 male obese patients with an average BMI of 44 kg/m^2, aged 19-58 years underwent MRI examination of the entire abdomen in a 1.5T MRI with a double-echo GRE-sequence [3].

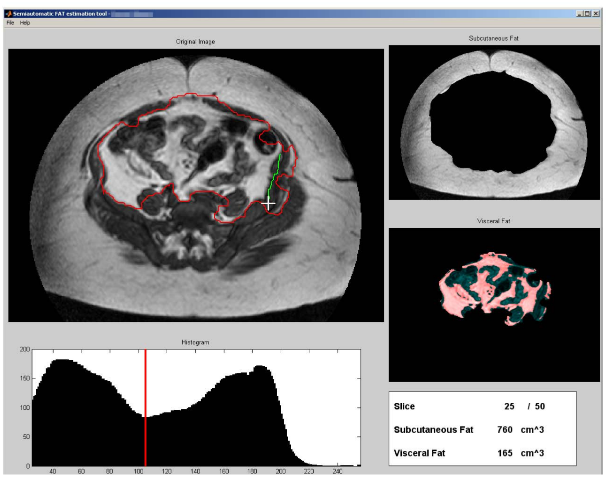

Figure 1: Sample screenshot of the custom-made user interface illustrating fat segmentation for data of a 49 year old female patient (BMI 48 kg/m^2). A large main window shows the original fat-fraction images and allows for a graphical correction of the computed SAT and VAT masks: correction of the SAT and inspection of the VAT masks can be intuitively performed by using the left (green contour) and right mouse buttons, respectively. Windows on the right show the SAT (top) and VAT (middle) masks and resulting volumes (bottom). The threshold can be adjusted by dragging the red line in the histogram window (bottom left) which automatically updates the fat regions overlaid (in red) in the VAT mask. A voxel is assumed to contain 100% fat if the signal intensity is higher than the threshold value [4]. The entire data set may be easily explored by scrolling through any of the displayed images.

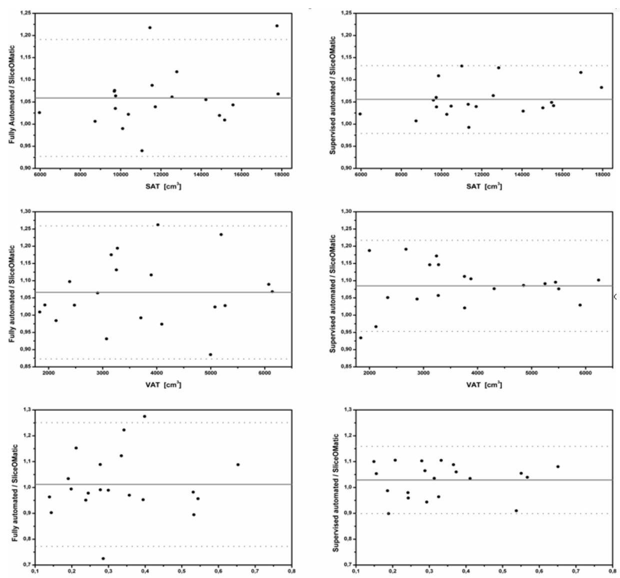

Figure 2: Inter-method comparison of fully automated (left) and supervised automated fat estimation (right) compared to manual assessment using SliceOMatic. SAT (top) and VAT (middle) were systematically overestimated with the custom-made tool, while VAT/SAT (bottom) agreed well with the standard of reference. Variation was substantially lower after manual correction.

Results

Fully automated processing with the tool running on a standard PC (2.6 GHz Dual-Core CPU, 3.2 GB RAM) required 6 minutes per patient (20 slices) and 4 additional minutes for visual inspection (total processing time: 10 minutes). Evaluation with SliceOMatic required an average of 21 minutes. The coefficient of variation (CV) between fully automatic processing with the algorithm compared to SliceOMatic was 6, 10, and 12% for SAT, VAT, and VAT/SAT, respectively. Manual correction of the non-supervised segmentation results reduced the CV to 4, 7, and 6 % (see Fig. 2).

Conclusion

Manual analysis of abdominal fat with available tools like SliceOMatic is sufficiently accurate but rather time consuming. Automated assessment of SAT and VAT in obese patients is generally prone to errors. After manual correction, however, the results were in good agreement with the standard of reference. The combination of automated processing with visual inspection (supervised automatic) is therefore considered to hold great promise for fast and sufficiently accurate fat quantification, especially in super-obese patients, where MR image quality tends to be reduced.

References

[1] J. Machann et al., Radiology 2010;257:353-63.
[2] J. Kullberg et al.; Int J Obes 2007;3:1806-17.
[3] F. Springer et al., Invest Radiol. 2010:45(8):484-90
[4] J. Lancaster et al., J Magn Reson Imaging 1991;1:363-369.