Time-effective MRI-based quantification of visceral adipose tissue (VAT) in morbidly adipose patients

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Target audience: Radiologists, MR physicists and other researchers interested or working in the field of MRI-based fat quantification.

Introduction/Purpose: Obesity is a growing health-care problem in most industrialized countries and is strongly associated with a variety of disorders, such as insulin resistance, type 2 diabetes or cardiovascular disease. Body fat has been shown to be a better disease predictor than anthropometric measures like BMI or waist circumference and visceral adipose tissue (VAT) is a key factor in risk assessment. While MRI-based VAT assessment is common, image acquisition and tissue segmentation are generally time consuming. Simplified methods, often based on partial data analyses have been reported for less obese subjects [1, 2], but evidence on the performance in morbidly obese patients (BMI > 40 kg/m^2) is still lacking. This study aimed to evaluate whether VAT volumes of representative slice positions can be used to estimate total VAT in such patients.

Materials and Methods: Seventy morbidly obese patients (mean BMI 47.2 kg/m², 47 females) were scanned at 1.5 T (Philips Achieva XR, two-point Dixon sequence, 50 slices, thickness 10 mm, gap 0.5 mm, acquisition time 160 s plus breathing intervals) before and after a two-week, low-energy diet (mean intake around 900 kcal/day). A semi-automated software tool [3] was used for fat segmentation (Fig. 1). VAT estimates of single slices (VAT_1) and blocks of five adjacent slices (VAT_5) centered at the level of spinal landmarks (lumbar discs L1/2–L5/S1) and at the umbilicus were compared to total volume VAT_T (from diaphragm to pelvic floor, reference value). Statistical measures of agreement were the coefficient of determination R^2 of a linear regression through the origin as well as the standard deviations σ_1 / σ_5 of the differences between volume predictions from VAT_1 / VAT_5, respectively, and the actual VAT_T (Bland-Altman analysis).

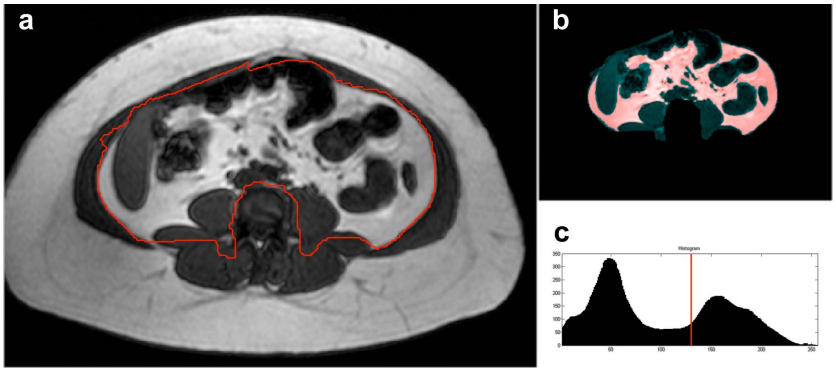

Fig. 1. Interface of the semi-automated VAT segmentation tool showing a slice at L3/4. **a:** VAT ROI boundary after manual correction of automatic segmentation attempt. **b:** overlay of current VAT selection in transparent red. **c:** histogram plot with threshold between non-fat (left) and fat tissue (right) contributions (peaks).

Results: VAT could be segmented successfully in all 70 patients. Total VAT analysis per patient involved an average of 37 slices and took approximately 20 minutes. Measurements of VAT_1 and VAT_5 required around 2 and 5 minutes, respectively. Total VAT values ranged from 1.4 to 9.2 (mean 5.1) L for females (n=47) and from 3.0 to 15.0 (mean 8.7) L for males (n=23). The best agreement for VAT_1 estimates of VAT_T was found at the level of L3/4 for females (R^2=0.83, σ_1=761 ml) and at L1/2 for males (R^2=0.86, σ_1=1,092 ml, Figs. 2 and 3). At these slice levels, VAT_1 made up an average fraction f_1=4.6 % and f_1=3.9% of VAT_T for female and male subjects, respectively. Corresponding VAT_5 estimates agreed slightly better in both groups (R^2=0.86, σ_5=681 ml and R^2=0.91, σ_5=919 ml, respectively). Agreement at the umbilical level was generally poor ($\sigma_{1/5}$=1,740–2,284 ml) with levels being located between 7 slices above and 16 slices (spacing 10.5 mm) below L4/5 (n=140). Individual changes after diet ranged from +614 to -1,168 (mean -160) ml for females and from +327 to -1,020 (-321) ml for males.

Discussion: As already observed in less obese patients [1], single-slice volume estimates at the level of lumbar discs were a good VAT predictor in morbidly obese patients. Overall accuracy varied with disc level and gender; absolute (relative) volume deviations were smaller for female (male) subjects. Best 1- and 5-slice agreements were found at L3/4 for female and at L1/2 for male patients. Analysis of more slices was found to be beneficial in both genders, in slight contrast to previous results in less obese women [2]. The resulting absolute accuracies are not suited to determine small VAT volume differences as previously reported by others [4].

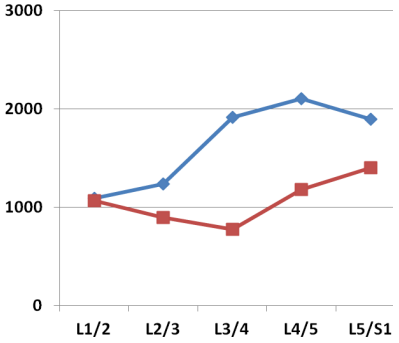

Fig. 2. Standard deviations σ_1 [ml] of differences between single-slice VAT estimates ($f_1 \cdot VAT_1$, see text) at lumbar disc levels L1–L5 and reference values (VATT) in morbidly obese patients (red: 47 females, blue: 23 males).

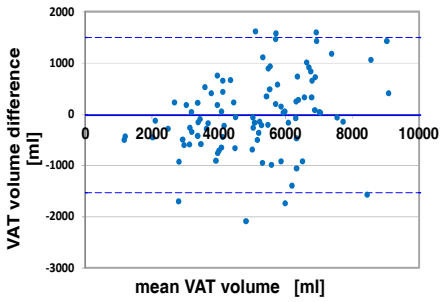

Fig. 3. Sample Bland-Altman plot illustrating differences ($f_1 \cdot VAT_1 - VAT_T$) between volumes predicted from VAT1 at L3/L4 and total VAT in 47 females. Solid and dashed lines indicate bias as well as lower and upper limits of agreements (bias±1.96·σ_1).

Conclusion: VAT volumes of morbidly obese patients can be reliably analyzed within 2 minutes by single-slice estimates at lumbar disc levels L3/4 (females) or L1/2 (males). Accuracy may be slightly improved at the expense of 3 more minutes needed for the processing of 5 slices. The assessment of volume changes as those encountered under minor therapeutic interventions like diets, however, requires a full quantification of all abdominopelvic MR images.

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References: [1] G. Maislin et al., Obesity 2012. [2] F. Springer et al., Eur J Radiol 2012. [3] G. Thörmer et al., JMRI 2013. [4] W. Shen et al., Obesity 2012.