Software for fully automatic quantification of abdominal fat with manual correction option

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Introduction/Purpose

Abdominal fat is associated with an increased risk for metabolic and cardiovascular diseases. MRI is well suited for a selective depiction of fat and a quantification of subcutaneous (SAT) and visceral adipose tissue (VAT). A manual segmentation is relatively accurate but rather time consuming [1]. An automatic analysis is user-independent but also prone to errors caused by anatomical variations and imaging artifacts seen in obese patients [2]. Therefore, we have developed a custom-made software for automatic quantification of abdominal fat that allows manual correction and have performed a preliminary evaluation on the data of 10 obese patients.

Materials and Methods

Ten (9 female, 1 male) obese patients with an average BMI of 35 and an average age of 19 underwent MRI examinations of the entire abdomen in a 1.5T scanner (Intera, Philips, The Netherlands) with a T1-weighted, fat-selective gradient echo (GRE) sequence (two stacks with 40 transverse slices each, slice thickness/gap = 8/2 mm, TR/TE = 83/6 ms, field of view = 500×500 mm^2, matrix = 512×512). A custom-made software was developed under Matlab (Mathworks, MA) that uses active contours (Snakes) to automatically define the boundaries between background, SAT and VAT in each image. The VAT volume is separated from lean tissue by setting an intensity threshold in the corresponding histogram of the VAT mask [1, 2]. The user interface allows to adjust the VAT and SAT contours as well as the threshold (Fig. 1). The results of the manual segmentations by two independent observers were compared with those after automatic analysis. Percent deviations with respect to the mean observer (manual) value were analyzed with paired two-sided t-tests (significance level 5%). A Kolmogoroff-Smirnov (KS) test was performed to test for the normal distribution of the percent deviations between automatic and manual volumes. The fat content V_{ref} of a reference phantom (Fig. 2) was determined both automatically and manually to estimate the absolute accuracy of the method.

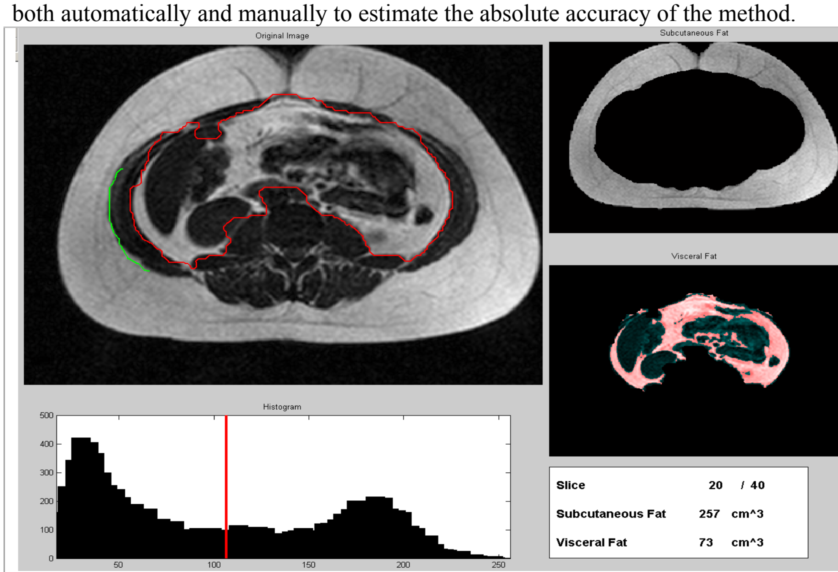

Fig. 1. Automatic segmentation of VAT and SAT in a 18 year old female patient (BMI: 36 kg/m^2). Windows to the right show the SAT (top) and VAT (middle) masks and resulting volumes (bottom). Threshold can be adjusted by dragging the red line in the histogram window (bottom left) which automatically updates the fat regions overlaid (in red) in the VAT mask. The main window (top left) is used for interactive definition and correction of the SAT and VAT contours.

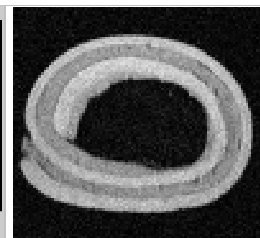

Fig. 2. Representative slice (T2w, fat-selective GRE sequence) of the reference fat phantom. Porcine back fat with an independently determined volume (V_{ref}=1415 ml) was wrapped around pieces of turkey breast.

Pat #	SAT				VAT			
	Obs. 1	Obs. 2	Auto	DEV [%]	Obs. 1	Obs. 2	Auto	DEV [%]
1	6012	6048	6004	-0.4	1121	1209	1378	+18.3
2	8985	10103	10461	+9.6	11221	11181	11749	+4.9
3	11068	11062	11067	0.0	2549	2430	2853	+14.6
4	11820	11944	11944	+0.5	1586	1665	1942	+19.5
5	9011	9032	9032	+0.1	1726	1619	2080	+24.4
6	15918	15955	15992	+0.3	3878	4126	4541	+13.5
7	10324	10271	10214	-0.8	2088	2224	2501	+16.0
8	20313	20145	20161	-0.3	3190	3968	4165	+16.4
9	20536	20403	20381	-0.4	3366	3462	4562	+33.6
10	14455	14485	14485	+0.1	1741	2009	2128	+13.5

Tab. 1. Resulting volumes (in ml) for manual (Observer 1 and 2) and automatic (Auto) fat quantification for all patients. Deviations (DEV) between manual and automatic methods were calculated as (Auto-Manu) / Manu × 100% with Manu = (Obs.1 + Obs.2) / 2.

Results and Discussion

Manual analysis of the reference sample (Fig. 2) was very accurate; the fat volume of the tissue phantom was overestimated by only 1.2%. Tab. 1 shows the detailed results after manual and automatic analysis of the patient data. The interobserver variations of the manual analysis were not significant with mean values of +0.6% for SAT ($p=0.338$) and 2.6% for VAT ($p=0.081$). Automatic analysis (segmentation and thresholding) took an average of 6 minutes per patient. On average, the automatic VAT and SAT volumes were (rounded) 17±8% ($p<0.001$) and 1±3% ($p=0.397$) higher than the manually derived. Statistical analysis of the VAT differences suggest a normal distribution (KS $p=0.824$) with an acceptable standard deviation of 8% around a highly significant bias. This bias can be explained by a systematic underestimation of the VAT threshold and thus an overestimation of the VAT volume. The outlying VAT and SAT values for patient #2 are probably due to the celiac association of fatty tissue in males, which should be the subject of further studies. The large VAT error observed for patient #9 was due to severe banding artifacts that lead to false contours.

Conclusion

These preliminary results suggest that the combined approach holds great promise for a fast (6 min) and sufficiently accurate fat quantification.

References [1] J. Lancaster et al., J Magn Reson Imaging 1991;1:363-369. [2] V. Positano et al., J Magn Reson Imaging 2008;28:403-410.