ACCURATE ADIPOSE TISSUE SEGMENTATION FROM SINGLE GRADIENT ECHO PHASE IMAGES BY ADAPTIVE LOCAL THRESHOLDING

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Motivation: The precise assessment of adipose tissue distribution is required in a wide variety of applications [1] and can be achieved using MRI [2]. To obtain images showing these compartments, spin echo (SE) and gradient echo (GRE) images can be used, each of the methods having their advantages and drawbacks. Spin echo images usually take a long time to acquire and expose the patient to a high amount of SAR. Often one single gradient echo image is not sufficient for a precise AT measurement due to a high amount of intensity non-uniformities present in these images. More advanced approaches, such as DIXON [3], are more time consuming and are not available on all scanners. Here, we propose an automated AT segmentation procedure based on the acquisition of one single GRE image, thus reducing the acquisition time while maintaining a maximal availability on most any scanning system. The images are acquired in opposed-phase condition and the phases image is used for quantification. This makes contrast in the magnitude image a negligible factor and allows a flip-angle reductions only limited by the desired SNR level.

Materials and Methods: The proposed method uses a standard spoiled gradient echo sequence (TR = 25 ms, TE = 2.38 ms, $\alpha = 15°$) for the acquisition of axial image slices. Using these parameters and, an image matrix of 320 * 240 elements, five image slices can be acquired in 12 s and thus in a breathold, if required.

Both, magnitude and phase images are used for a further processing. The magnitude image is used to remove the signal-free background. This is done using a region grow algorithm with a threshold set to the mean plus three times standard deviation of the background region, found so far (see Fig. 1b). The detected background areas are then excluded from further processing. The proposed method exploits the high contrast in the phase images in between fat- and water-based tissues. However, due to inhomogeneities in the B1 and B0 fields, a smoothly varying phase divergence prohibits a segmentation of the images by simply using a fixed threshold throughout the whole image. Thus, the phase image is divided into regions of 20 * 20 pixels. A histogram with 32 bins is obtained in each of these regions, slightly lowpassed and then the highest peak is detected (see Fig. 1c). This peak is expected to correspond to either the phase of the water- or the fat- class at that particular spot (the corresponding phase of the other class is obtained by shifting that value by π). After having obtained these two values for all regions in the phase image, the values are sorted into the local fat- and water-phase by grouping adjacent elements with a similar phase, thus incorporating the property of a smoothly varying phase (result for the fat class can be seen in Fig. 1d). The values are then fitted in between the centers of the square regions using a cubic smoothing spline (see Fig. 1e for the estimated local phase of the fat class). To obtain the two local thresholds for the separation of fat and water tissues, the interpolated local phase estimates are shifted by $\pm\pi/2$. By applying these two thresholds to the original phase image, the masks for water- and fat- based tissues can be obtained (see Fig. 1f).

A concentric fat-water phantom consisting of a oil-filled cylinder inside of a water-filled cylinder was used to evaluate the algorithm's absolute accuracy. To evaluate performance on real data, covering GRE and SE images of the abdomen were acquired. The SE images were segmented manually and used as gold standard. One threshold in each image was chosen to remove the background from tissue, another threshold to separate AT from water tissue.

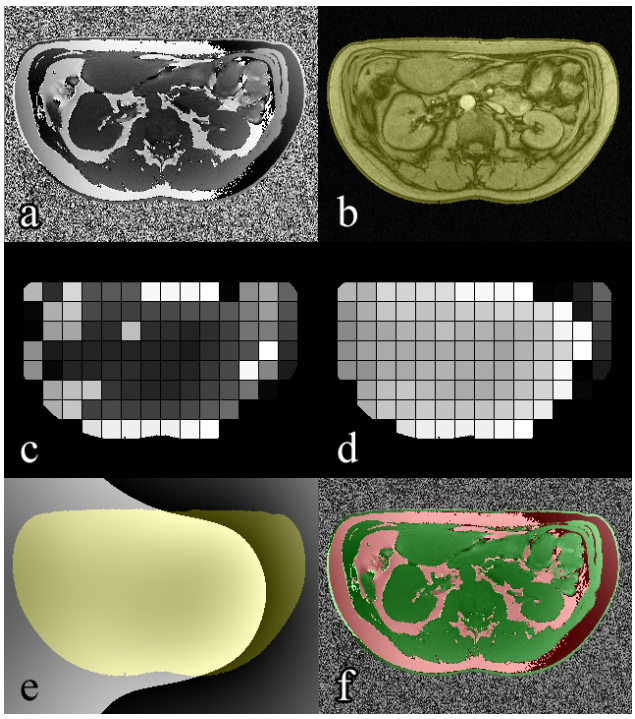

Figure 1: a) The original phase image **b)** the magnitude image and the body, obtained by the region growing (yellow) **c)** the histogram maxima, found in the 20*20 px regions **d)** the intensities, corresponding to the fat phases in each region **e)** the estimated phases of fat, obtained by cubic fitting spline **f)** the final fat (red) and water (green) areas overlaid to the original phase image.

Results: The phantom study showed a high precision of the proposed method. The fat-area of the inner cylinder was measured to 5.83 cm² compared to a real area of 5.73 cm² (1.75 % error) and the area of the water cylinder was measured to 61.93 cm² compared to a real area of 61.32 cm² (0.99 % error). In the evaluation with real image data a systematic overestimation of total tissue could be observed (7.8 ± 0.9 %). A comparison of the results showed, that the skin was barely visible in the SE images and did therefore not contribute to the tissue. The precision for the class of fat was fairly good with a men deviation of 5.8 ± 8.7%. Since the contrast in the phase images is very good, the large standard deviation of this value is supposed to be mainly caused by the high amount of partial volumes in the SE images.

Conclusion: An automatic algorithm for fat quantification using a fast GRE acquisition technique is proposed. The lower time consumption compared to a SE approach can either be used to acquire a larger amount of images in the same time or to increase spatial resolution. The high contrast in between water- and fat- based tissues in the GRE phase image, combined with an adaptive threshold enables a precise segmentation and quantification. Evaluation using a phantom indicate a high accuracy of the proposed method.

[1] M. Krotkiewski et al., *J. Clin. Invest.* 1983:72:1150-1162. **[2]** N. Abate et al., *J. Lipid . Res.* 1994:35:1490-1496. **[3]** W. Dixon, *Radioloy* 1984:53:189-194.