Quantification of fatty septa in skeletal muscle of the lower leg by T1-weighted MRI and correlation to anthropometric and metabolic data

J. Machann[1], M. Bottcher[1], F. Springer[1], N. Stefan[2], H-U. Haring[2], C. D. Claussen[3], A. Fritsche[2], and F. Schick[1]

[1]Department of Diagnostic Radiology, Section on Experimental Radiology, Tübingen, Germany, [2]Department of Endocrinology, Metabolism, Clinical Chemistry, Nephrology and Angiology, Tübingen, Germany, [3]Department of Diagnostic Radiology, Tübingen, Germany

Introduction

Besides the pure adipose tissue, as subcutaneous adipose tissue or visceral adipose tissue, the so-called ectopic fat in organs which do normally contain no fat at all but are affected by insulin resistance, as intramyocellular lipids (IMCL) in skeletal muscle or hepatic lipids (IHL) in the liver, play an important role in the pathogenesis of insulin resistance and type 2 diabetes [1,2]. IMCL can reliably be determined by ^{1}H MRS and show a negative correlation to insulin sensitivity [1]. Probably, besides IMCL, also the amount of fatty septa nestled along the muscle fiber bundles might be of importance. As single voxel ^{1}H MRS does not allow a quantification of this intermuscular fat (IMF) depot, the aim of this study was to quantify IMF by T1-weighted MRI and to compare the results with anthropometric and metabolic data in a cohort at increased risk for type 2 diabetes mellitus (T2DM).

Material and Methods

In this cross-sectional study, 249 volunteers (97 males, 152 females) at increased risk for T2DM due to obesity (BMI > 27 kg/m²), family history of T2DM, impaired glucose tolerance and/or gestational diabetes were examined. MR was performed in the early morning after overnight fasting on a 1.5 T whole body imager (Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany). T1-weighted images of the right calf were recorded by a fast-spin-echo sequence with following measurement parameters: TE = 16 ms, TR = 650 ms, turbo factor 3, 7 slices, slice thickness 6 mm, in-plane resolution 0.35 x 0.45 mm, acquisition time 47 sec. Volunteers were in supine position with the most extended part of the lower leg in the circular polarized extremity coil of the manufacturer. Postprocessing was done by a home-written program based on Matlab. The slice with the largest cross-section was automatically selected and subcutaneous fat (SCAT), IMF and muscle mass were quantified in cm². Bone marrow of tibia and fibula were excluded. Figure 1 shows the principle of postprocessing and quantification of the different areas. Percent body fat (PFAT) was determined by bioimpedance analysis (BIA-101; RJL Systems, Clinton Twp., MI) and insulin sensitivity by a hyperinsulinemic glucose tolerance test (glucose infusion rate, GIR) immediately after the MR examination.

Results

Mean age (45.3 vs. 48.7 years) and BMI (28.8 kg/m² vs. 30.0 kg/m²) were comparable in males and females, but females have significantly higher PFAT (35.5% vs. 26.7%). Males are characterized by significantly higher muscle mass compared to females (94.5 cm² vs. 71.5 cm²) and have significantly more IMF (2.2 cm² vs. 1.5 cm²). In contrast, females have significantly higher SCAT (39.8 cm² vs. 22.5 cm²). There is a negative correlation between age and SCAT (r = -0.22 in females and r = -0.40 in males). IMF and SCAT show a strong correlation to BMI (IMF: r = 0.65/0.35, SCAT: r = 0.63/0.62 for females/males. GIR was negatively correlated with IMF in both, females (r = -0.46) and males (r = -0.35) and somewhat less with SCAT (r = -0.32/-0.24. Figure 2 depicts images of a male volunteer with a BMI of 40 kg/m² showing low SCAT but high IMF and a male volunteer (BMI 25.5 kg/m²) with low IMF but comparatively high SCAT.

Discussion

Quantification of intermuscular fat (IMF) is possible by standard MR techniques which are available at all MR-units. Due to the different T1-times, muscle can be reliably separated from adipose tissue – however, it is not possible to detect intramyocellular lipids (IMCL) with this approach. Special so-called spectral-spatial techniques can visualize IMCL distribution [3] but are on the other side not capable of quantifying muscle volume, as water containing compounds are completely suppressed. Males are characterized by higher amount of IMF compared to females but have less SCAT. This is comparable to the abdominal adipose tissue distribution, where males have more visceral adipose tissue but also less SCAT compared to females [4]. Besides IMCL also IMF seems to be involved in the pathogenesis of insulin resistance, as shown by the negative correlation with GIR.

References

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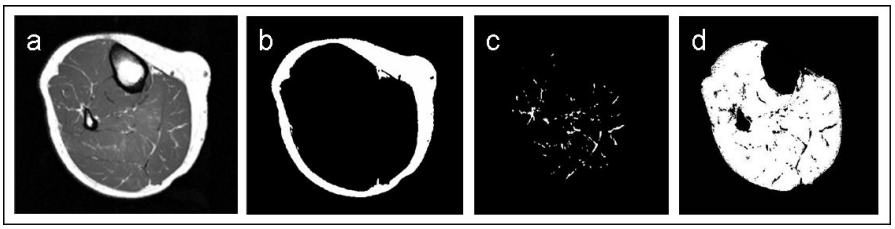

Figure 1: *(a) original T1-weighted image and principle of postprocessing for quantification of subcutaneous adipose tissue (SCAT, b), intermuscular fat (IMF, c) and muscle mass (d) from lower leg. Fatty bone marrow of tibia and fibula is excluded.*

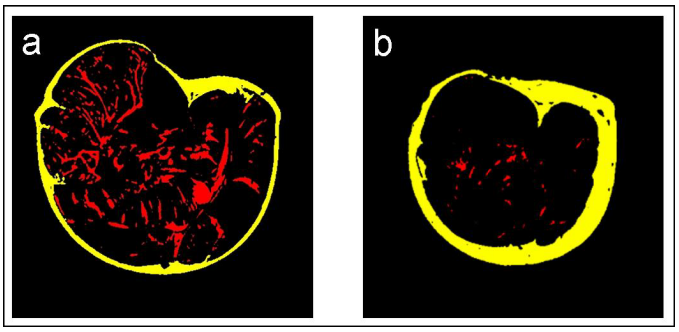

Figure 2: *(a) male volunteer with low SCAT (yellow) and high IMF (red) and (b) male volunteer with relatively high SCAT but low IMF.*