Water-fat imaging of supraclavicular brown and white adipose tissue at 1.5T: Initial results in healthy volunteers

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Target audience: Researchers interested in quantification of brown adipose tissue, in obesity and type 2 diabetes.

Introduction: In mammals, brown adipose tissue (BAT) can be present in addition to white (WAT). While WAT primarily serves as energy storage, BAT helps regulating body temperature by uncoupling ATP production in the cellular respiratory cycle leading to heat production. In its active state, BAT has the capacity of consuming relatively large amounts of energy making the tissue interesting for research on obesity and related type 2 diabetes. The current gold standard for BAT imaging is cold-stimulated ^{18}F-fluorodeoxyglucose, positron emission tomography - computed tomography (^{18}F-FDG, PET-CT). However, the fact that examined subjects are exposed to ionising radiation limits its application. Pioneering magnetic resonance imaging (MRI) studies in rodents and humans[1,2] have demonstrated the potential of water-fat separated MRI as a non-ionising imaging methodology for BAT. This by demonstrating differences in fat fraction and R2* between BAT and WAT at fields ≥3T. So far, no results from widely available clinical 1.5T systems have been presented.

Purpose: To set up and evaluate high resolution mapping of fat fraction and R2* for BAT detection on a clinical 1.5T MR-scanner.

Methods: Healthy volunteers (5 males, 5 females, age 26±7 [19-44] years, BMI 24.6±3.1) were imaged on a 1.5T clinical MR system (Philips Achieva, Philips Healthcare, Best, Netherlands) using a spoiled 3D multi gradient echo sequence, a 16 channel neurovascular receive coil and a 4 min 40 s scan in free breathing. Scan parameters were: TR/TE_1/ΔTE = 32.7/1.68/2.87 ms, 6 unipolar echoes, flip angle 6°, water fat shift = 0.25 pixels, parallel imaging acceleration = 1.5 in anterior-posterior (fold-over) direction, field of view = 450x200x50 mm, acquired and reconstructed voxelsize 1.0x1.0x2.0 mm, number of signal averages = 2. Water and fat separation was performed using a multi-scale version of a previously described method[3] using a multi-peak fat resonance model, a single R2* (decoupled determination) and a regularization parameter mu=10. A mild and short cold exposure (18.5°C, 20 min, standardized clothing) was applied directly before MRI. The quality of the water and fat images was visually assessed by a radiologist using a four-grade scale (severe/moderate/mild/no artifacts). The first two grades were given when image quality was suspected to impact on adipose tissue measurements. Adipose tissue properties of the supraclavicular (i.e. suspected BAT region, denoted BAT) and the subcutaneous (SAT) depots were compared both visually and using ROI measurements. The visual evaluation was performed to determine if a lower fat fraction in the supraclavicular depot could be detected by the naked eye and was performed independently by one radiologist and two engineers. The ROI measurements in both BAT and SAT were performed using three methods to study the dependence of the method used, all based on anatomically predefined ROIs (Figure 1). The BAT ROIs were defined from retrospective studies of PET-CT scans showing activated BAT. *Method 1:* "Range limited" - Manual identification of the ROI in all slices with range limits on fat fraction (>50 %) and R2* (<50 s^{-1}). *Method 2:* "Eroded" – Same tissue as in method 1 but with addition of morphological erosion (6 voxel neighbourhood) to reduce partial volume effects from neighbouring tissues. *Method 3:* "Manual" – Fully manual delineation of the adipose tissue ROIs, considering partial volume effects, performed in a single slice. The delineation was made in the water image, considering also the fat fraction and R2* data.

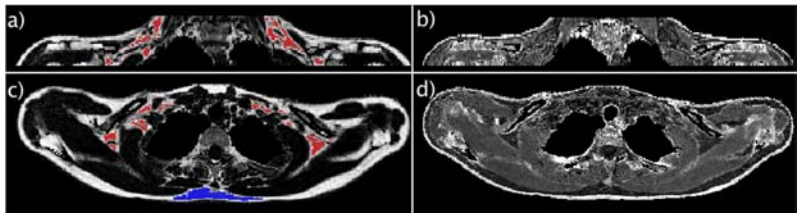

Figure 1: Fat fraction (a,c) and R2* images (b,d) with the ROIs from method 2 ("Eroded") illustrated in color in the fat fraction image (red for BAT and blue for SAT).

Results: All volunteers successfully underwent the imaging procedure. The number of images with the different quality scores were 0/1/6/3, respectively. The image scored as "moderate" contained a supraclavicular adipose tissue region with low fat signal intensity possibly caused by an imaging artefact of unknown source. The six images scored as "mild" contained intensity non-uniformities likely caused by coil sensitivity differences. These were however not seen to affect the fat fraction images. No water-fat swaps were seen. All evaluators identified lower fat fractions in suspected BAT regions in the same 6 subjects. The radiologist identified an additional subject. The measured fat fractions agreed well with the visual evaluation and were generally lower in BAT than in SAT (Table 1). The R2* measurements showed less consequent differences. All measurements of fat fraction and R2* differed significantly between method 1 and 2. Fat fractions differed significantly between methods 1 and 3, while no measurement differed significantly between methods 2 and 3.

Table 1: Fat fraction (FF) and R2* measures from 10 volunteers in brown (BAT) and subcutaneous adipose tissue (SAT) using tree different methods.

Method	FF - BAT	FF - SAT	R2* - BAT	R2* - SAT
1, "Range limited"	78.8 ± 4.8	84.2 ± 6.5	22.9 ± 1.4	21.5 ± 3.7
2, "Eroded"	83.8 ± 4.7	86.1 ± 6.0	21.2 ± 1.4	20.5 ± 3.6
3, "Manual"	83.7 ± 5.7	87.0 ± 6.1	21.4 ± 4.0	22.6 ± 6.3

Discussion: The focus on the supraclavicular depot in this work allowed the use of a small field of view and high resolution mapping within a reasonable scan time and with a procedure likely also applicable to children and adolescence. Results were neither compared to biopsy nor PET-CT reference. Hence, no conclusion on the cause of the differences between BAT and SAT regions can be drawn. It was noted that the fat fraction measurements varied largely between subjects (BAT, 72-92% and SAT, 75-96%, depending also on the method used). The reason for this large variation cannot be determined by this study. Possible explanations could be differences in adipocyte size or presence of BAT. These measurements were seen correlated to BMI (BAT, r=0.77-0.82 and SAT, r=0.74-0.77, depending on the method used).

Conclusion: An MRI protocol for time efficient and high-resolution quantification of fat fraction and R2* at 1.5T has been described and evaluated in volunteer subjects. The capability of the described method of detecting tissue differences between suspected BAT regions and SAT has been demonstrated. Also, the importance of considering partial volume effects when performing ROI measurements has been demonstrated.

References:

[1] Hu HH, et al. JMRI 35(4):938-42. 2012. **[2]** Hu, HH et al. ISMRM 2012, 1268. **[3]** Berglund J, et al. MRM 67(6):1684-93; 2012.