Quantification of Fatty Acid Compositions Using MR-imaging and Spectroscopy at 3 T

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Introduction

Multi-echo imaging has previously been used for fat/water separation and fat quantification [1,2]. The same technique may potentially also be able to differentiate different fat types depending on the amount of unsaturated fatty acids. The fatty acid composition of adipose tissue is not only dependent on the diet, but may also be interesting in e.g. chronic inflammations [3]. Also, the method might be used to detect differences in fat composition in patients with various forms of excess adipose tissue (e.g. lymphedema) as compared to normal fat [4]. This phantom study aims at investigating the potential of multi-echo imaging and spectroscopy to quantify the fraction unsaturated fatty acids (UF) and compare the results against known values.

Material and methods

Six 50 ml oil phantoms with various fatty acid compositions were measured using a birdcage head coil in a 3 T Tim Trio Siemens scanner (Siemens Medical Solutions, Erlangen, Germany). The known UFs were: coconut, 8 %; palm, 54 %; peanut, 80 %; olive, 85 %; sunflower, 89 % and rapeseed oil, 92 %. For both tested methods, the signal contributions from the fat resonances originating from -C**H**$_2$-CH=CH- (A) and -CH$_2$-C**H**$_2$-COOR (B) were used to estimate UF according to: UF = 0.5*A/B [5].

Spectroscopy:

A PRESS-localized spectroscopy voxel was placed in each phantom and measured using: TE = 30 ms, TR = 2 s, voxel size = 10x10x20 mm^3, bandwidth = 1200 Hz and number of signal averages = 32. Quantification of the signal contributions of resonances A and B was performed using the AMARES-algorithm included in jMRUI v2.1.

Multi-echo imaging:

A spoiled multi gradient echo sequence with twelve TEs was used for multi-echo imaging. The first TE was chosen to the shortest possible and the following TEs were separated by 3 ms. The remaining parameters were set to: TR = 800 ms, flip angle = 40°; bandwidth = 1500 Hz/px, FOV = 180x180 mm^2, slice thickness = 5 mm, matrix size = 128x128 and number of averages = 4. A linear least-squares approach with a built-in correction for off-resonance effects and dephasing due to field inhomogeneities similar to the self-calibrated algorithm described by Yu *et al* was used to separate the signal contributions of resonances A and B [6]. The used frequencies were fixed and based on a soybean oil model.

Results

Both multi-echo imaging and spectroscopy methods successfully quantified the UF of the oil phantoms, although the spectroscopy method showed an overall overestimation (Figures 1-2). A regression analysis between known and estimated UF indicated a high accuracy of the multi-echo imaging method with a slope of 0.886 and intercept of 3.80 %. The corresponding values for spectroscopy were 0.956 and 11.3 %. The correlation (R^2) of both methods was larger than 0.99.

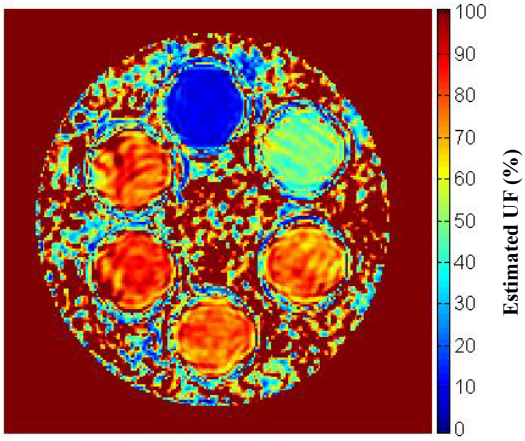

Figure 1. *Resulting UF-image using multi-echo imaging. Coconut oil is seen in the top middle and phantoms of increasing UF follow clockwise.*

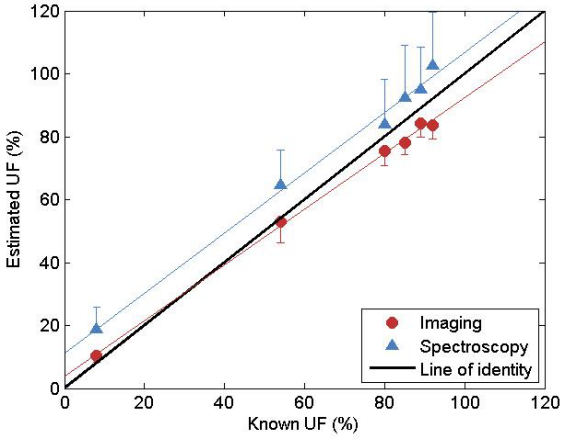

Figure 2. *Estimated UF using multi-echo imaging and spectroscopy methods plotted against known UFs. Regression lines for spectroscopy and imaging results are shown in blue and red, respectively. Error bars represent one standard deviation.*

Discussion and conclusion

This experiment successfully demonstrates the ability of multi-echo imaging and spectroscopy to evaluate fatty acid compositions. Spectroscopy does not offer the spatial resolution obtained when using multi-echo imaging. Also, for spectroscopy there is the added difficulty of J-coupling which might explain the overestimated results. For both methods, absolute quantification requires that relaxation effects are taken into account. The outcome of this study shows the large potential of multi-echo imaging to provide information not only on the fat content, but also on the fatty acid composition.

References

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