IN VIVO {^{1}H}-^{13}C NMR SPECTROSCOPY OF THE HUMAN CALF ON A 7-T WHOLE-BODY MR TOMOGRAPH

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TARGET AUDIENCE: Researchers interested in NMR spectroscopy with X nuclei at ultra-high B_0 fields.

INTRODUCTION: The carbon isotope ^{13}C is detectable in living tissue by NMR (natural abundance = 1.1 %, $\gamma_{13C} = 6{,}726 \cdot 10^7\ T^{-1}\ s^{-1}$, spin I = ½). ^{13}C NMR spectroscopy (^{13}C MRS) is applied to observe various metabolites *in vivo*, e.g. triacylglycerides (TAG), glycogen, glucose, amino acids, without or with administration of ^{13}C labeled drugs[1,2]. High field strengths and ^{1}H spin decoupling enhance signal and information content of ^{13}C NMR spectra. The aim of this study was to optimize the degree of ^{1}H–decoupling for a model solution by varying the parameters of two different decoupling schemes and then to obtain B_0–shimmed ^{1}H–decoupled ^{13}C NMR spectra of the human calf on an experimental 7–T whole–body MR tomograph.

METHODS: The ^{13}C resonances of TAG in vegetable oil resemble the ^{13}C resonances of TAG in the human calf. Therefore we used a 280 ml vegetable oil phantom for tests and optimization of antenna system, 1–pulse sequence, and ^{1}H-decoupling technique. ^{13}C detection was done with TR = 4.0 s, pulse width = 0.25 ms (B_1), spectral width Δf = 2 kHz, 2048 data points. In phantom experiments two decoupling schemes were optimized: WALTZ-4[3] and continuous wave (cw). For WALTZ-4 we varied the decoupling pulse width, the delay between the decoupling pulses, the total decoupling period and the decoupling field strength (B_2), for cw the length of irradiation and B_2. The optimized decoupling parameters were applied to *in vivo* ^{13}C NMR spectroscopy of the calf of a healthy 29–year–old female volunteer. A home–built ^{13}C/^{1}H double–resonant transmit/receive surface coil was used (loop diameter = 7.5 cm). Figure 2a shows the position of the coil on the calf (GRE ^{1}H image). All measurements were performed on a 7–T scanner (MAGNETOM 7 T; Siemens Healthcare, Erlangen, Germany).

RESULTS: Optimal decoupling was obtained with duration of decoupling in the order of 50 % of the acquisition time and frequency of cw pulse set at the dominant methylene ^{1}H resonance. WALTZ–4 achieved a lower degree of decoupling due to B_2 inhomogeneities. The resulting ^{13}C NMR spectra (methylene region) of the model solution are shown in Fig. 1, the in vivo spectra in Fig. 2. Due to the collapse of the multiplets upon decoupling (fig. 1b and 2c) the different methylene groups can be distinguished. For the spectral region 29 ppm – 31 ppm decoupling provided an increase of SNR by a factor of 1.6 (compare 1b vs. 1a and 2c vs. 2b) for the model solution and for the human calf.

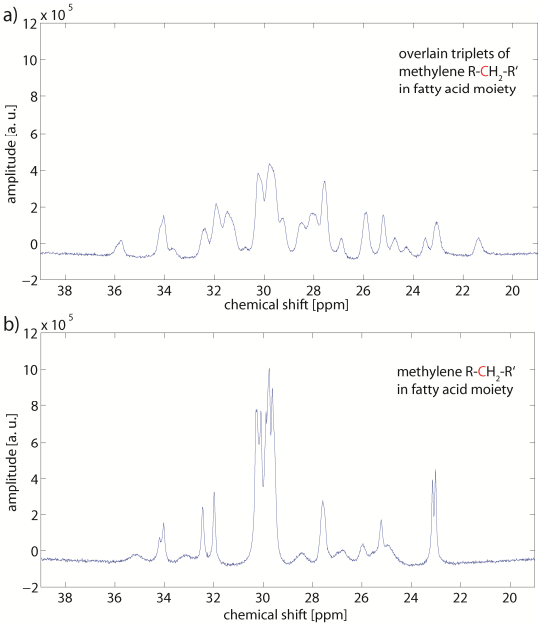

Fig. 1: Methylene region of ^{13}C NMR spectra obtained at B_0 = 7 T from vegetable oil without (a) and with cw ^{1}H–decoupling (b) (n_{ex} = 4, measurement time 16 sec).

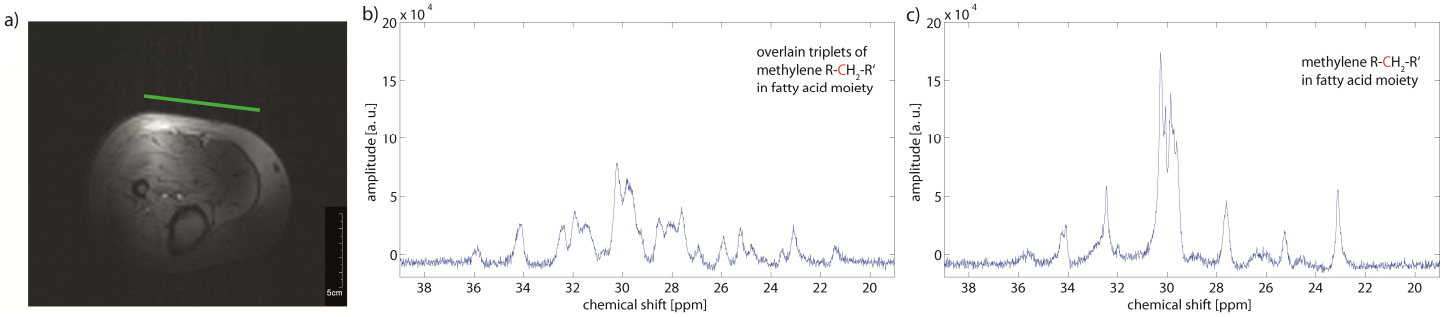

Fig. 2: (a) ^{1}H image with position of the coil (green) on the human calf (GRE sequence: TE/TR = 2.36 ms / 5.2 ms, matrix = 128×128, FOV = (250 mm)^2, slice thickness = 5 mm). (b, c) *In vivo* ^{13}C NMR spectra showing methylene resonances of TAG in the human calf (n_{ex} = 32, measurement time about 2 min) obtained without (b) and with cw ^{1}H–decoupling (c).

CONCLUSION: Sequence parameters for {^{1}H}–^{13}C MRS were optimized in a 7–T whole–body scanner and applied to ^{13}C MRS of the human calf *in vivo*. The obtained natural–abundance ^{13}C NMR spectra are dominated by the resonances of fatty acids (TAG). High–field {^{1}H}–^{13}C MRS opens up new vistas in the noninvasive analysis of carbohydrate (glycolysis, citric acid cycle), amino acid, and lipid metabolism.

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