Detection of hepatic glycogen by 1D ISIS localized ^{13}C MRS at 7T.

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Purpose: Over 20 years ago ^{13}C MR Spectroscopy has been introduced and validated as the method of choice for the assessment of skeletal muscle and hepatic glycogen content[1]. The following applications in metabolic studies focused especially on pathophysiology of type 2 diabetes mellitus [2-4] and skeletal muscle glycogen consumption during the exercise. However, inherent low sensitivity of ^{13}C MR restrained the volume and/or time resolution of the measurement at lower field strength considerably[2-4]. Localized 1D-CSI has previously been proposed and introduced at B_0 of 4T only[5]. Increase of observed signal-to-noise ratio and increased spectral resolution at 7T MR Systems promotes especially X-Nuclei MR measurements and ^{13}C MRS of glycogen was already tested in skeletal muscle[6,7]. The aim of this study was to implement and test a ^{13}C MRS localization scheme suitable for the measurement of hepatic glycogen at 7T in short acquisition time. One dimensional slice selective version of recently introduced fully adiabatic extended ISIS sequence[8] was proposed and tested for this purpose

Methods: All measurements were performed using a 7T MR system (Siemens Healthcare, Erlangen, Germany) equipped with a ^{1}H/^{13}C body surface coil (STARK CONTRAST MRI Coils Research, Erlangen, Germany). The surface coil was designed for the application in the abdomen and thorax region and consist of slightly curved 18 cm large transmitter loop with 2 smaller (14 cm) receiver elements combined to quadrature detection operating at ^{13}C resonance frequency (74.73 MHz) as well as Tx/Rx loop of 16 cm for ^{1}H imaging and for proton decoupling (297.2 MHz).

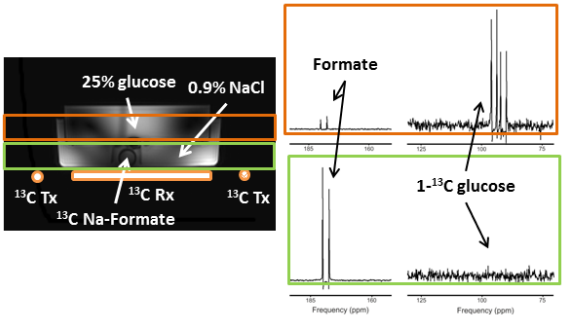


Fig.1. Glucose/Formate phantom used for localisation test measurements (left) and ^{13}C MR Spectra obtained by placing the 1D ISIS slab over the glucose solution (orange) and on the formate sphere (green) – right.

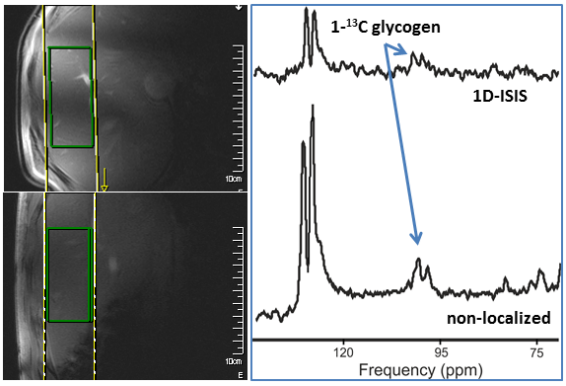
Initial measurements aimed to test the RF-pulse and localization performance of the used sequence and were performed on two compartment phantom (Fig. 1): A small glass sphere (volume of 2.3 cm^3) containing 0.8 g of 99% ^{13}C enriched sodium formate was submerged in large plastic container with 1L of 0.9% saline solution. Another plastic container filled with 1.3L of 25% naturally ^{13}C abundant glucose solution was placed within the large one in the distance of 2,5 cm from the bottom of the large container. Concentrations of sodium formate and glucose were sufficient to provide enough ^{13}C signals with single pulse acquire scan. The phantom was placed atop the surface coil in the magnet isocenter.

In vivo measurements were performed on three healthy volunteers (2m/1f, age: 34±5 y; BMI= 22±1 kg.m^{-2}) without any history of liver or other metabolic disease. All volunteers were positioned in the right lateral position with right liver lobe above the coil center and hepatic tissue filling the most of the sensitive volume of the coil.

One dimensional slice selective version of recently introduced fully adiabatic extended ISIS sequence[8] (BW= 20000 Hz, TR= 1s in vivo and 10s on phantom, NA= 256 in vivo and 1 on phantom, Tx/Rx frequency centered on sodium formate 177 ppm or 1-^{13}C glucose 95 ppm) using GOIA pulses (5000 µs) for adiabatic inversion and block pulse (500 µs) for excitation without ^{1}H decoupling and acquisition triggering was used for signal localization. In all cases a 1D localized slab (thickness of 2 cm in phantom experiments or 4 cm in vivo situation) was placed parallel to the coil plane at the distance to cover either formate sphere or glucose layer in the experiments on phantom (Fig. 1) or to avoid the largest portion of subcutaneous thorax muscles in the in vivo experiments (Fig. 2). Block pulse adjustments and in vivo non-localized acquisitions were performed by a simple pulse acquire sequence (block pulse of 500 µs) with the same bandwidth and frequency adjustments as used for the localization scheme. Shimming was performed automatically in a cuboid volume placed exclusively in hepatic tissue.

Spectra were processed offline using the AMARES algorithm as implemented in jMRUI and prior knowledge for respective resonances. Glycogen signals were fitted by two lines with identical frequency and different line-widths each[9]. Signal intensities and CRLBs with and without localization were determined.

Fig.2. Left - Axial and sagittal images of human liver with the depiction of 1D ISIS slab selection (yellow) and adjustment volume (green). Right – 1-^{13}C glycogen region ^{13}C MR Spectra of human liver acquired with (upper trace) and without (lower trace) localization scheme.



Results and Discussion: Results of the localization performance tests are depicted in the Fig. 1. Suppression of outer volume signal reached 89 % in the case of sodium formate and 97% in the case of 1-^{13}C glucose signal. In vivo measurements (Fig.2) showed sufficient signal to noise of 1-^{13}C glycogen in both acquisition. Localized spectra presented with SNR of 3.5±0.9 and CRLBs of 25±2 for the 1-^{13}C glycogen doublet at 100.5 ppm within 4:16min of signal acquisition.

Conclusion: The 1D-ISIS ^{13}C-MRS scheme applied at 7T presented optimal localization performance and sufficient signal to noise in relatively short acquisition times. These gains will be utilized in future metabolic studies focused on the hepatic metabolism in type 2 diabetes and non-alcoholic fatty liver disease.

References:

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