Reproducibility and Absolute Quantification of Human Liver Glycogen from ^{1}H Decoupled ^{13}C Spectra Using Exact RF Coil Information, MRI and an External Reference at 1.5T

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Purpose

The purpose of the study is to get a quantitative measure on the reproducibility of the absolute liver glycogen concentration obtained from continuous wave ^{1}H decoupled ^{13}C MRS combined with MRI data and RF-coil data, and the influence of respiratory motion.

Introduction

Quantification of liver glycogen concentration from ^{13}C-spectra is hampered by the lack of an accurate internal reference signal in the spectrum. Pulse-and-acquire experiments using surface coil localization have the advantage of high SNR, little signal loss of resonances with very short T2 such as glycogen, robustness for motion, and the absence of chemical shift displacement of the selected volume. The disadvantages of this approach, however, is the spatial inhomogeneity of sensitivity and excitation, and the a contamination of the liver glycogen signal by glycogen in the abdominal muscle tissue. This contamination is estimated to be in the order of 10% to 15% *(1,2).*

Materials and Methods

Three healthy volunteers and one individual just recovering from an incidental food poisoning were included in this study. Measurements were repeated twice with a complete repositioning of the dual tuned flexible RF-coil (Medical Advances 710-GE-64) between the sessions. A standard 1.5T GE Signa MR-scanner (running a FIDCSI with 2.5ms adiabatic excitation pulse, TR=301; 2000 averages; sampling rate 5kHz) equipped with a second decoupling channel (SMIS 3010 decoupler console; running 60ms CW decoupling during ^{13}C acquisition) was used.

Eight axial images (gradient echo, TR=100ms , TE=4.2ms, FOV 25 cm) obtained in apnea at full expiration covering the whole liver were recorded on which markers were attached to define the position of the square 11.3x11.3cm ^{13}C-coil. By numerical integration of the Biot-Savart equation:

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} I \oint_C \frac{\vec{dl}_C \times \vec{dr}_1}{r^2} \qquad [1]$$

(C denoting the coil contour), the exact RF field map (3D dataset) was calculated. Using this magnetic field strength map the Bloch equations were solved for the experimental 2.5 ms adiabatic half passage excitation pulse, resulting in a 3D transverse magnetization $M(\vec{B}(\vec{r}), t = T_p)$ in which the transmit and receive properties of the coil were taken into account. The experimental sensitivity and excitation corrected liver volume (SEV) as 'seen' by the ^{13}C coil is found by matching the liver-region-segmented images with the simulated magnetization values calculating:

$$\mathrm{SEV} = \int_{\text{liver}} M(\vec{B}(\vec{r}), t = T_p)\, dV \qquad [2]$$

in which T_p is the pulse-time. To correct for differences in coil loading, a separate acetone containing phantom was attached. With $A_{glycogen}$ being the hepatic glycogen resonance area at 100.5 ppm and $A_{acetone}$ being the area of the acetone resonance at 210ppm as determined by spectral fitting *(3),* the absolute liver glycogen concentration can be estimated from:

$$C_{glycogen} = \frac{A_{glycogen}}{A_{acetone} \cdot \mathrm{SEV}} \qquad [3]$$

Due to respiration the liver moves during the registration of the spectrum. To examine the influences of this motion on the reproducibility the program (written in IDL™) calculates the effective volume also for user definable displacements.

Results

As measure for the *reproducibility* (expressed in %) is the standard deviation in the mean of the differences found in two equivalent measurements divided by the average of all values (cv) is taken.

variable	average (n=4)	standard. deviation (n=4)	reproducibility cv (n=4)
volume (MRI)	1.14 dm^3	0.32 dm^3	7.8%
V_{eff}(z=0 cm)	2.15 a.u	0.25 a.u.	10.0%
V_{eff}(z=2 cm)	2.12 a.u.	0.16 a.u.	8.0%
V_{eff}(z=4 cm)	1.81 a.u.	0.26 a.u.	22.2%
$C_{glycogen}$(z=0cm)	3.63 i.u.	1.21 i.u.	24.6%
$C_{glycogen}$(z=2cm)	3.58 i.u.	0.94 i.u	11.7%
$C_{glycogen}$(z=4cm)	4.18 i.u.	0.92 i.u.	17.2%

Table 1: Overview experimental data (z distance below expiration)

It is further noteworthy that for the normal volunteers an average liver glycogen concentration of 3.95±0.62 i.u. (n=6) was found whereas for the starved volunteer suffering from food poisoning 2.31±0.34 i.u. (n=2) for a displacement z=2cm.

Discussion

Because the MRI images are acquired at full expiration (corresponding with z=0) the liver is during MRI relative to the RF coil differently positioned than during MRS, during which the volunteer is normally breathing. For a normal breathing person an average displacement z of 1 to 5 cm may be expected. Best reproducibility is found for z=2cm. To determine the offset value which best reproducibility more z values have to be examined. To get values for absolute liver glycogen concentration (instead of institutional units) liver biopsies are required, to verify the validity of Eq.[3]. The significant difference in concentration found between the healthy volunteers and the volunteer with food-poisoning might be an indication for the validity of the proposed method.

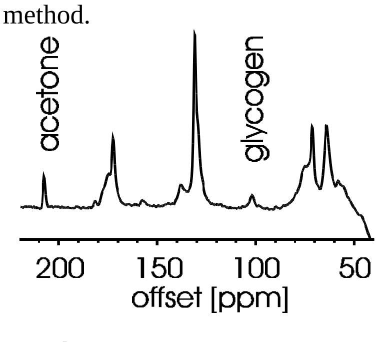

Figure 1: Typical ^{1}H decoupled ^{13}C liver spectrum the showing intense lipid resonances, the C_1 resonance and acetone resonance. Negative contributions below 50ppm are due to the used RF pulse characteristic.

Conclusion

A new method has been described for the absolute quantification of hepatic glycogen. The sensitivity and excitation corrected volume (SEV) of the RF coil is calculated by matching RF coil specific information with MRI images covering the whole liver. The reproducibility of the proposed method is dependent on the assumed relative average coil to liver displacement. The best reproducibility was obtained at average liver displacement of 2cm.

References

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