Reproducibility of in vivo localized MRI and MRS measurements in human liver

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Introduction:
There is a growing awareness that non-invasive techniques can potentially provide biomarkers of liver disease to allow monitoring of disease progression and treatment. Phosphorous magnetic resonance spectroscopy (MRS) has proved to be useful in the assessment of chronic liver dysfunction [1]. Other MR techniques, including diffusion weighting imaging and ^{1}H MRS, may be of value. As part of a wider study to investigate non-invasive hepatic biomarkers of disease progression, an ^{1}H MR imaging/spectroscopy protocol has been developed, which considers some of the problems related to movement, tissue heterogeneity and the presence of large vessels. In order to assess the reliability of this protocol, the intrasubject variability of relevant ^{1}H MR imaging/spectroscopy parameters was investigated.

Methods: All MR studies were performed using a 1.5T Philips Achieva system (Best, The Netherlands) (software r2.1) with local research committee ethical approval. A female healthy control was studied 12 times over a 5 month period. A 4-channel SENSE–Body coil and Q-Body coils were used. The protocol included routine survey images, 3D T1 weighted gradient echo MRI, diffusion weigthed imaging (DWI), followed by ^{1}H MRS.

3D T1 weighted gradient echo MRI: MR images were acquired during a single breath-hold and subsequently used for registration.

DWI was performed axially using breath-hold single-shot echo planar imaging (TR=2430 ms, TE=64 ms, 7 mm slice thickness with gap =1 mm, 375 FOV SENSE factor =2, diffusion gradients with three b values b=0, 200, 400 sec/mm^2 were applied in three directions. Isotropic ADC maps were calculated using all three b values. The mean ADC within the subsequent MRS volume of interest (VOI) was then measured.

1H MRS using single voxel PRESS with water suppression (TR=2 s; minimum TE=40ms) was obtained for metabolite and lipid measurement.. The 8 ml VOI was placed in the right lobe of the liver by an experienced radiographer, so as to avoid visible vessels, and in a reproducible position on the basis of orthogonal scout images. Acquisition was performed with breath holds in expiration lasting no more than 20 sec. Spectra were acquired in blocks of 8 averages. Unsuppressed water spectra were also acquired with TE=40, 60 and 135 ms for T2 measurements. Metabolite concentrations were estimated using water as a reference and estimated water content.

Water content: MR visible water content was estimated using external spherical water phantom by comparing MR signals from unsuppressed water spectra with the signal from the phantom acquired with STEAM sequence. Correction for coil loading and B_1 inhomogeneity were based on principle of reciprocity and approximation of the STEAM signal with $\sin^3$ dependency on B_1 [2]. It has been suggested that there might be two water compartments in liver: free “MR-visible” and “hydration/structured/bound” water [3]. STEAM spectra were also acquired with series of TE (15, 20, 30,40,60,80,100, 140,160,180, 270, 350), TM=14 ms, for more detailed T2 measurements.

Assessment of Reproducibility of Voxel Positioning: Using rigid body registration, the position of the VOI from the first MR examination was compared to the later examinations and reproducibility of placement was assessed by the volume of overlap.

Results:
Illustrative MR images showing the assessment of reproducibility of voxel positioning is shown in Fig 1. A representative ^{1}H MR spectrum is illustrated in Fig 2 Relevant MR measured parameters with coefficient of variation are summarized in Table 1.

Table 1.

MR measure	Cho	Water content	T2 water (PRESS)	T2 water (STEAM)	T2 lipids	ADC x1000	Voxel overlap
Mean	2.08 mM	46 %	51.8 ms	38.24ms	52.8 ms	1.034 sec/mm^2	69 %
CV %	10.8	7.4	11.0	6.0	4.8	9.0	10

Discussion and Conclusions:
Mean MR parameters are comparable to published values Cho [4], T2 values [5], and ADC [8] apart from the apparent water content, which is lower than that in literature obtained *ex vivo* after drying (77 %) [9]. This may be explained by the fact that not all compartments are MR visible in vivo. It is also clear that measurement of T2 in water was is more reproducible with STEAM acquisitions due to the wider range of TE available. An automated VOI placement based on the registration of the liver images will further improve the protocol.

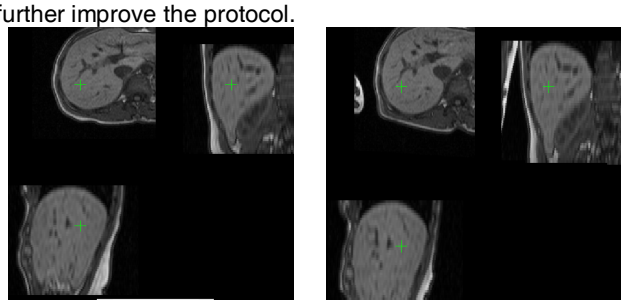

Fig.1 Example of an baseline, and registered followup , + represents VOI positioning

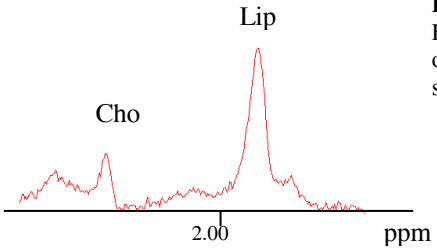

Fig. 2 Example of the 1H spectrum

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