Quantitative comparison of localized in vivo hepatic ^{31}P MRS at 7T.

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Purpose/Introduction

^{31}P-MRS provides unique information on hepatic energy metabolism *in vivo*. Alternations in hepatic energy metabolism are indicative for inflammatory and neoplastic liver diseases and were demonstrated in T2DM patients [1]. The major limitation of hepatic ^{31}P-MRS was low signal sensitivity at clinical scanners and from that resulting long acquisition times. Nowadays, several fold higher SNR is available at human whole body 7T MR scanners. The purpose of this study was to quantitatively test the feasibility of several localization schemes for *in vivo* hepatic ^{31}P-MRS at 7T in clinically acceptable measurement time.

Subjects and Methods

Data were acquired on a 7T MR system (Siemens Healthcare, Erlangen) using double-tuned surface coil (^{1}H/^{31}P) (RAPID Biomedical GmbH, Rimpar, Germany), with a diameter of 10 cm. During *in vivo* measurements volunteers (m/f=5/4; age, 28±7 years) were lying in the lateral position with the lateral lobe of the liver on the surface coil.

To assess the spectral quality of hepatic ^{31}P-MRS spectra were acquired by four different localization techniques (Fig.1a). **(i)** Slab selective ^{31}P-MRS was performed for a 3 cm-thick slab using a 1D-ISIS approach (TR 1.5 s; TE* 0.3 ms; 128 avg TA=3 min 12s). **(ii)** single voxel spectroscopy (SVS) of a 5×5×3 cm^3 liver volume was performed by 3D E-ISIS [2] (TR 3 s; TE* 0.3 ms; 72 avg; TA=3:42 min). **(iii)** For 2D-CSI measurements, a combination of 1D-ISIS selection of a 3 cm-thick slab with 2D-CSI phase (goISICS) encoding was used (TR 1.5 s; TE* 0.5 ms; matrix 12×12 interpolated to 16×16; 4*2 k-space weighted averages; TA 7:48 min) [3]. **(iv)** 3D-CSI (TR 1.5 s; TE* 0.5 ms; matrix 12×12×12 interpolated to 16×16×16; 4 k-space weighted averages; TA 20:15 min). Nominal and effective voxel sizes are summarized in Table 1. The spectral quality of the localization data (i.e., average SNR, linewidth, and Cramer-Rao lower bounds - CRLB) was determined. The acquired SNR was defined as the ratio between the amplitude of first γ-ATP FID point and the standard deviation (SD) of the noise of last 100 points in the unfiltered FID. Corrected SNR was estimated after volume and acquisition time normalization of acquired SNR. In case of 2D-CSI and 3D-CSI nine representative voxels from similar location as 3D-ISIS were quantified and their results were averaged.

Results

All methods provided data with high spectral quality regarding SNR, small linewidth and low CRLB(<11%). Corrected SNR (for voxel volume and acquisition time) was similar for all the methods. Slab selection by 1D-ISIS provided fair localization in the shortest measurement times with little chemical shift displacement errors (CSDEs) and low muscle tissue contamination (~7.5%) (Fig.1b). SVS by 3D-ISIS provided well-localized spectra of liver tissue in short measurement time (Fig.1c). 2D-CSI combined with CSDE-insensitive 1D-ISIS selection (goISICS) allowed fast metabolic 2D mapping (Fig.1d), while 3D-CSI enabled 3D mapping over a larger liver volume in longer measurement times (Fig.1e). Quantitative values are summarized in Table 1.

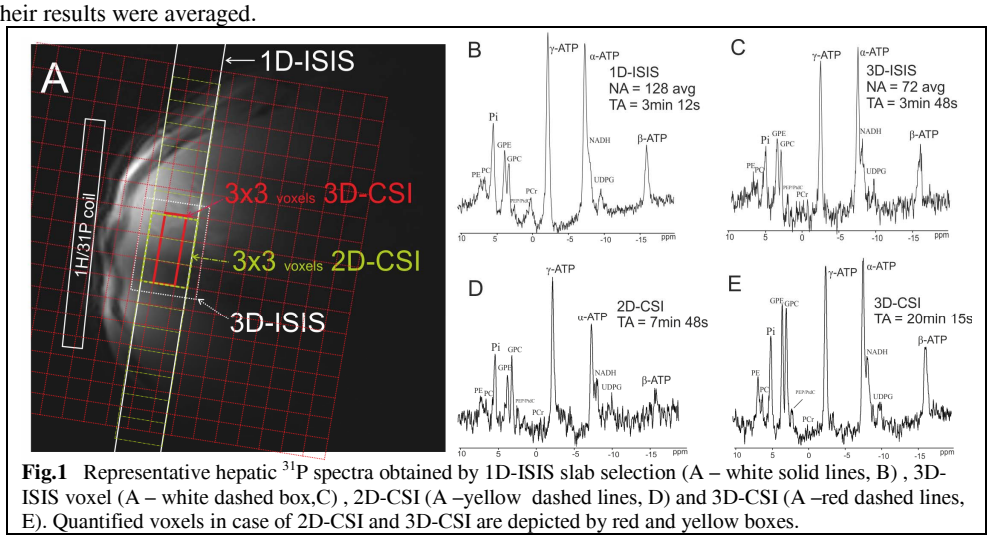

Fig.1 Representative hepatic ^{31}P spectra obtained by 1D-ISIS slab selection (A – white solid lines, B) , 3D-ISIS voxel (A – white dashed box,C) , 2D-CSI (A –yellow dashed lines, D) and 3D-CSI (A –red dashed lines, E). Quantified voxels in case of 2D-CSI and 3D-CSI are depicted by red and yellow boxes.

Table 1: Results of localization measurements obtained in nine healthy volunteers by four acquisition methods: SVS by 3D-ISIS, slab-selective 1D-ISIS, a combination of 1D-ISIS selection with 2D-CSI and 3D-CSI. Information about acquisition time (TA), nominal and effective voxel size, spectral quality (i.e., FWHM, acquired and normalized SNR and CRLB of γ-ATP) are provided.

	TA [min]	Nominal voxel size [cm^3]	Effective voxel size [cm^3]	FWHM$_{\gamma\text{-ATP}}$	Acquired SNR$_{\gamma\text{-ATP}}$	[c] Normalized SNR$_{\gamma\text{-ATP}}$	CRLB$_{\gamma\text{-ATP}}$
1D-ISIS	3:12	150[a]	150[a]	50 ± 24 Hz	9.7 ± 4.5	5.7±2.6	8.7 ± 3.3 %
3D-ISIS	3:42	75	75	34 ± 10 Hz	3.6 ± 0.9	5.6±1.4	7.6 ± 2.5 %
2D-CSI	7:48	8.33	24.65[b]	33 ± 10 Hz	2.4 ± 0.7	5.6±1.7	8.6 ±4.2 %
3D-CSI	20:15	4.63	26.11[b]	34 ± 11 Hz	4.8 ± 1.7	6.5±2.3	10.3 ± 2.7 %

[a] 1D-ISIS voxel size was estimated as cylinder with height of 3cm and radius of 4cm

[b] Effective voxel size of CSI methods due to k-space weighted acquisition. Factor 1.72 for 2D-CSI and 1.78 for 3D-CSI were used in all phase encoding directions according to Pohmann et al. [4] [c] Normalized SNR was corrected for acquisition time and effective voxel size

Discussion/Conclusion

The feasibility of commonly used ^{31}P-MRS localization techniques that are suitable for both localized MRS of focal lesions and semi-localized MRS for use in diffuse pathologies in the human liver was demonstrated at 7T. Voxel volume and acquisition time corrected SNR was similar for all the methods.

References

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