Fully adiabatic ^{31}P 2D CSI with negligible chemical shift displacement error at 7T

M. Chmelik[1], S. Gruber[1], S. Trattnig[1], and W. Bogner[1]
[1]MR Centre of Excellence, Department of Radiology, Medical University of Vienna, Vienna, Austria

Purpose/Introduction

^{31}P-MRS is a non-invasive tool which provides information about energy phosphate metabolites (ATP, PCr, Pi), intracellular pH, intracellular [Mg^{2+}], and (PME, PDE) involved in malignant processes [1]. The major limitation of ^{31}P-MRS at clinical scanners (e.g. 1.5 T) was low SNR and long acquisition times. Nowadays, ultra high field scanners provide several fold higher SNR but also increase of chemical shift displacement errors (CSDE) (~75% for 3.4kHz pulse between ß-ATP and PME at 7T) and higher B_1 inhomogeneities. These limitations can be solved by using ISIS localization with broadband GOIA pulses (~10% for 25kHz pulse between ß-ATP and PME at 7T) which provide spectra from single volume[2] or by 3D CSI with adiabatic excitation which is completely CSDE free but needs long acquisition time [3]. The purpose of this study was to implement fully adiabatic ^{31}P 2D CSI sequence with negligible CSDE at 7T based on 1D-ISIS/2D-CSI selection.

Subjects and Methods

Data were acquired on a 7 T and 3T MR systems (Siemens) using double-tuned surface coils (^{1}H/^{31}P) (RAPID Biomedical, Columbus, OH), with a diameter of 10 cm. CSDE in slice direction was tested on cylindrical phantom with three chambers filled with PCr (20mm middle chamber) and Pi (side chambers) (Fig.1a). Standard 2D-CSI and a novel hybrid 1D-ISIS/2D-CSI sequence were compared with following parameters (8x8 voxels, nominal resolution 25x25x6-24mm, TR 15s, TA 32min). Sequence was tested invivo in calf muscle of volunteers (n=4) with following parameters (AHP excitation, 10x10 voxels, nominal resolution 15x15x25mm, TR 3s, TA 6:13min)(Fig.2).

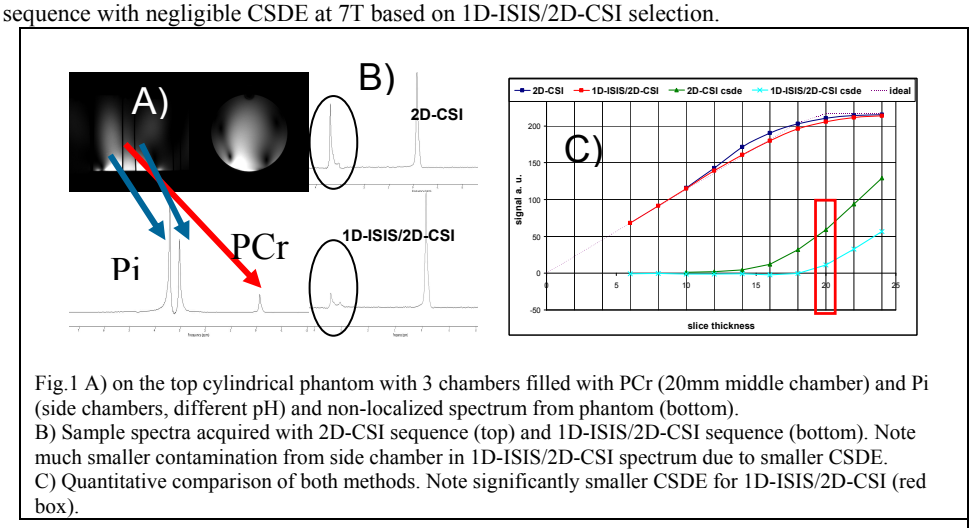

Fig.1 A) on the top cylindrical phantom with 3 chambers filled with PCr (20mm middle chamber) and Pi (side chambers, different pH) and non-localized spectrum from phantom (bottom).
B) Sample spectra acquired with 2D-CSI sequence (top) and 1D-ISIS/2D-CSI sequence (bottom). Note much smaller contamination from side chamber in 1D-ISIS/2D-CSI spectrum due to smaller CSDE.
C) Quantitative comparison of both methods. Note significantly smaller CSDE for 1D-ISIS/2D-CSI (red box).

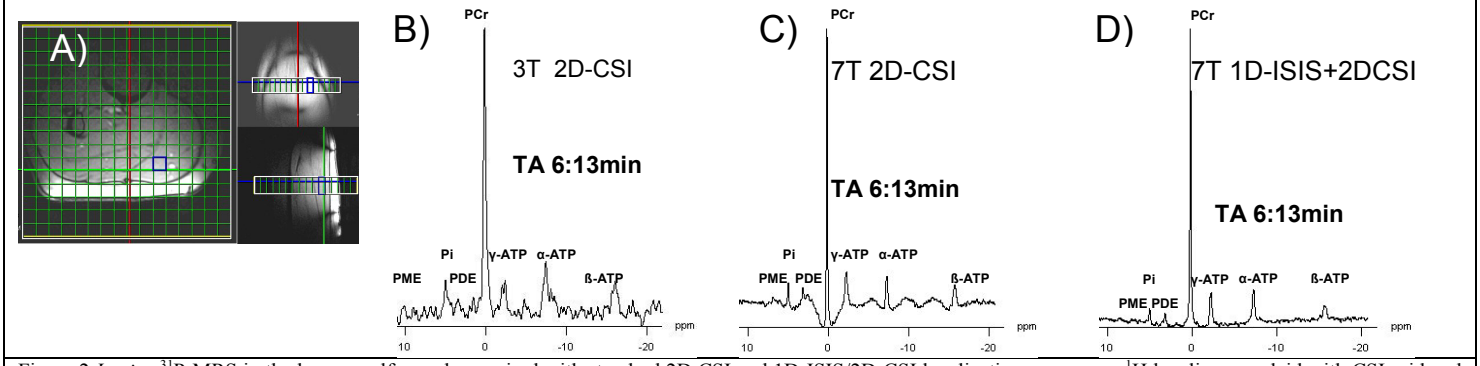

Figure.2 *In vivo* ^{31}P-MRS in the human calf muscle acquired with standard 2D CSI and 1D-ISIS/2D-CSI localization sequences. ^{1}H localizer overlaid with CSI grid and selected voxel (blue box) (A). Standard 2D CSI spectrum sample from 3T(B) and from 7T(C). New 1D-ISIS/2D-CSI spectrum sample from 7T(D).). Note significant increase of SNR (3T vs 7T) and baseline shape in (D) due to shorter pseudo-echo time (2.3ms for 2D-CSI vs. 0.4ms for 1D-ISIS/2D-CSI) and thus less 1st order phase correction.

Results

The new fully adiabatic ^{31}P 2D CSI sequence based on 1D-ISIS/2D-CSI selection was successfully compared with standard 2D-CSI sequence and tested in localization phantom (Fig.1) and in vivo (Fig.2). Pulse profile measurements (not shown) confirmed expected difference in bandwiths of pulses used for slice selection in 2D-CSI(1280 µs Sinc3 ~ 3.4kHz) and in 1D-ISIS/2D-CSI (5ms GOIA ~ 25kHz). Phantom measurements proved reduced slice direction CSDE with new sequence (Fig. 1 b and c) which is approximately 8 fold smaller for 1D-ISIS/2D-CSI. This means reduction from ~75% CSDE between ß-ATP and PME at 7T for 2D-CSI to ~10% CSDE between ß-ATP and PME at 7T for 1D-ISIS/2D-CSI. Fig.2 displays typical invivo calf muscle spectra difference between 2D-CSI at 3T, 2D-CSI at 7T and 1D-ISIS/2D-CSI at 7T.

Discussion/Conclusion

The presented 1D-ISIS/2D-CSI sequence allows in combination with AHP or BIR-4 excitation pulse fully adiabatic performance suitable to be used with B_1 inhomogeneous surface coils and reduces ~8 fold chemical shift displacement error in slice direction compared to conventional 2D-CSI with Sinc3 selective pulse at 7T. Such 2D ^{31}P MRSI has the potential to be applied in both clinical research and possibly clinical routine at 7T.

References

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[3] Chmelik et al. MRM 2008 Oct;60(4):796-802