ECHO-PLANAR SPECTROSCOPIC ^{13}C AND ^{31}P NMR IMAGING OF HUMAN CALF MUSCLE *IN VIVO* ON A WHOLE–BODY 7-T MR TOMOGRAPH

Andreas Korzowski[1], Tanja Platt[1], and Peter Bachert[1]
[1]*Dept. of Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Baden-Württemberg, Germany*

TARGET AUDIENCE: Researchers interested in fast NMR spectroscopic imaging techniques for X nuclei at ultra-high B_0 fields.

INTRODUCTION: ^{13}C and ^{31}P NMR spectroscopy allow noninvasive observation of metabolic processes *in vivo*, in particular the turnover of triacylglycerides (TAG) and high–energy phosphates, respectively. NMR spectroscopy with rare nuclei takes advantage from high B_0 by enhanced signal–to–noise ratio (SNR) and increased spectral resolution. In conventional 2D Chemical Shift Imaging (CSI) the total measurement time is proportional to the number of steps $N_1 \times N_2$ of two orthogonal phase encoding gradients. Fast spectroscopic imaging techniques such as echo–planar spectroscopic imaging (EPSI)[1,2,3] where information from one spatial direction is simultaneously encoded with the spectral information, reduce the measurement time strongly by a factor N. The purpose of this study was to demonstrate feasibility of ^{13}C and ^{31}P EPSI of the human calf muscle on a 7–T whole–body MR tomograph.

METHODS: An adapted EPSI sequence was implemented according to Wilhelm *et al.*[2] and Ulrich *et al.*[3] using trapezoidal instead of sinusoidal readout gradients (Fig. 1). The repeated application of alternating readout gradient pairs generates a gradient echo (GRE) train where one spatial and the spectral information are encoded simultaneously. The measurement parameters for 2D–EPSI were: matrix = 8×8 (8 phase encoding steps, 8 sampling points per GRE), 256 gradient pairs (duration of one pair: 500 µs), gradient ramp time = 80 µs. In the gradient flat phase (duration: 90 µs) a single GRE is sampled, generating 256 GRE pairs with spatial / spectral dwelltime 11.25 µs / 500 µs, receiver / spectral bandwidth 88 / 2 kHz and 7.8 Hz spectral resolution. EPSI datasets were reconstructed with an own MATLAB (The MathWorks, Natick, MA, USA) routine utilizing only one of the two GRE trains. To evaluate spectral quality, EPSI datasets were compared to datasets obtained with a commercial CSI sequence (Siemens Healthcare, Erlangen, Germany) with identical FOV (matrix = 8×8, spectral bandwidth = 2 kHz, spectral resolution = 7.8 Hz). Post processing of EPSI and CSI datasets included only zero– and first–order phase corrections. Measurements were performed on a 7–T scanner (MAGNETOM 7 T; Siemens) with home–built ^{31}P/^{1}H and ^{13}C/^{1}H double resonant surface coils (diameter = 10 cm and 7.5 cm, respectively). The results shown in Fig. 2 were acquired from the calf muscle of a healthy 29–year–old female volunteer.

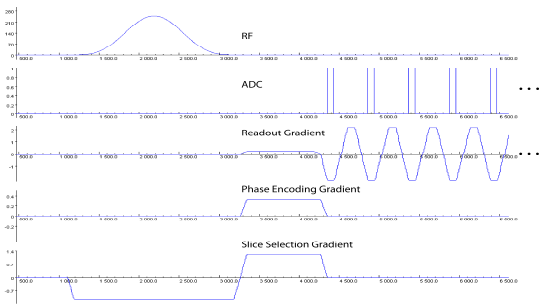

Fig. 1: Scheme of the implemented EPSI sequence.

RESULT and DISCUSSION: Fig. 2 shows the results of ^{13}C / ^{31}P EPSI measurements compared to conventional CSI for a representative voxel *in vivo*. Sequence parameters were adjusted to obtain the same image matrix in equal total acquisition times. In ^{31}P spectra the SNR of the phosphocreatine resonance (PCr) in the marked voxel was SNR_{EPSI} = 20.7 and SNR_{CSI} = 16.1, in ^{13}C spectra the SNR of the central methylene resonance (Meth) at δ = 30 ppm was SNR_{EPSI} = 5.6 and SNR_{CSI} = 4.7. The lower SNR of CSI spectra resulted from a suboptimal rf excitation in the commercial sequence (in our case about 20% lower SNR). Theoretically, reconstruction employing the 2nd GRE train would yield an SNR gain of factor $\sqrt{2}$ for EPSI datasets. Both spectroscopic imaging techniques yield good spectral quality with comparable SNR per unit time.

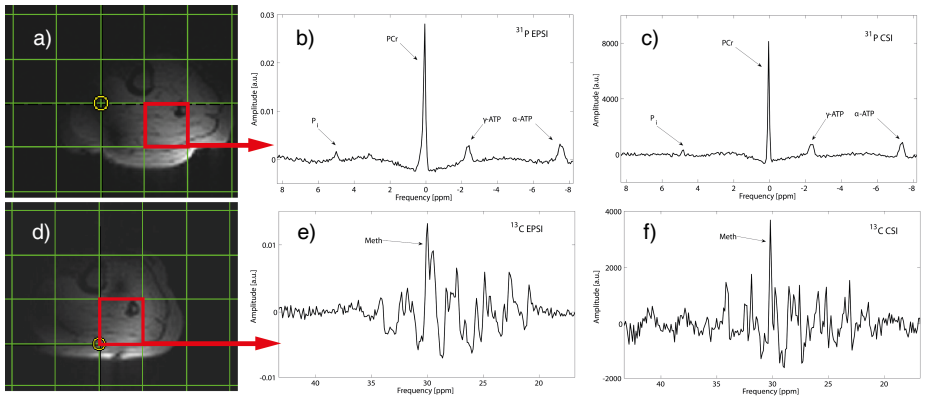

Fig. 2: (a–c) ^{31}P measurement: spectra obtained with EPSI (b) and CSI (c) from the voxel indicated in (a) (red box, nominal voxel size = 37.5×37.5×30.0 mm³). (d–f) ^{13}C measurement: spectra obtained with EPSI (e) and CSI (f) from the voxel indicated in (d) (red box, nominal voxel size = 37.5×37.5×40.0 mm³). Sequence parameters ^{1}H GRE image: FOV = (300 mm)², slice thickness = 4 mm, matrix = 128×128, TR / TE = 5.2 / 2.6 ms, 1 average. Sequence parameters ^{13}C / ^{31}P EPSI and CSI: FOV = (300 mm)², slice thickness (^{13}C / ^{31}P) = 40 / 30 mm, matrix = 8×8, TR = 500 ms, Δf = 2000 Hz, 256 datapoints, 32 / 4 averages (EPSI / CSI), total EPSI and CSI acquisition time = 130 s for both nuclei.

CONCLUSION: Localized high–resolution *in vivo* ^{13}C and ^{31}P NMR spectra were obtained at B_0 = 7 T from human calf muscle with an EPSI technique. In ^{31}P spectra the peaks of ATP, PCr, and inorganic phosphate are resolved. In comparison to conventional CSI, EPSI enables much shorter acquisition time, but yields comparable SNR per unit time[4]. The method can be extended to functional spectroscopic studies with X nuclei at 7 T.

REFERENCES:

1. Posse S, *et al.* High speed ^{1}H spectroscopic imaging in human brain by echo planar spatial-spectral encoding. Magn. Reson. Med. 33: 34–40 (1995).
2. Wilhelm T., Bachert P. *In vivo* ^{31}P echo–planar spectroscopic imaging of human calf muscle. J. Magn. Reson. 149: 126–130 (2001).
3. Ulrich M, *et al.* ^{31}P–{^{1}H} echo-planar spectroscopic imaging of the human brain *in vivo*. Magn. Reson. Med. 57: 784–790 (2007).
4. Pohmann R, *et al.* Theoretical evaluation and comparison of fast chemical shift imaging methods. J. Magn. Reson. 129: 145–160 (1997).