

Comparison of ^{31}P -MRS at 3T and 7T for localized and non-localized acquisition

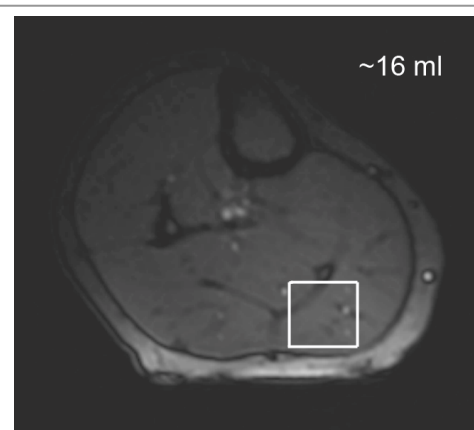
W. Bogner¹, M. Chmelik¹, S. Trattnig¹, and S. Gruber¹

¹Department of Radiology, Medical University of Vienna, Vienna, Austria

Introduction:

Phosphorus magnetic resonance spectroscopy (^{31}P -MRS) allows the study of human energy metabolism non-invasively. Until now long measurement times and relatively low spatial resolution have limited the clinical use of ^{31}P -MRS. At 7T the spectral resolution is significantly better than at lower field strengths. The SNR of surface coil localized fully relaxed ^{31}P spectra was almost doubled between 3T vs 7T in the human calf muscle [1] and 4T vs 7T in the human brain [2]. In addition, T_1 relaxation times at 7T were significantly shorter than at 3T, which leads to additional signal-to-noise ratio per unit time [1]. However, these studies did not consider differences in the sensitive volume of the coils. Only localized MRS may allow unbiased comparison of spectral quality between different field strength. In our study we have performed ISIS localized ^{31}P -MRS in the human calf muscle at 3T and 7T to assess the differences in spectral quality.

Fig. 1: localization of single voxel ISIS sequence with $2.5 \times 2.5 \times 2.5 \text{ cm}^3$ (=16ml) voxel size for ^{31}P -MRS in the human calf muscle.



Methods and Materials:

All measurements were performed on a 3T TIM Trio system and a 7T Magnetom system (Siemens, Erlangen, Germany). At both scanners double-tuned surface coils ($^1\text{H}/^{31}\text{P}$) with identical geometry (RAPID Biomedical, Ohio, USA), with a diameter of 10 cm, were used. The ^{31}P channels were tuned to 49.9 MHz and 120.3 MHz, respectively. Data in the calf muscle of five healthy volunteers (three male; age, 26 ± 4 years old) were acquired. Institutional Review Board approval and written, informed consent were obtained. Phantom measurements were performed on a large phantom filled with inorganic phosphate solution. Loaded/unloaded quality factors of both coils were determined by a network analyzer.

For both, the volunteers and the phantom, single voxel (SV) localized and surface coil localized ^{31}P -MRS was performed at both field strengths. Voxel positioning and coil distance were kept constant. SV localization was performed by extended ISIS with high bandwidth (25 kHz) gradient modulated adiabatic GOIA pulses for accurate volume selection with negligible chemical shift displacement errors [3]. The sequence parameters were: TR = 6 s; TE* = 0.3 ms; spectral width 5000 Hz; 2048 points; 10 ms BIR-4 (cos/sin) excitation pulse; 5 ms W(16,4)-GOIA pulses; 2.5 cm isotropic resolution; 32 averages + 6 dummy scans; total measurement time 3:48 min. Fully relaxed surface coil localized spectra were obtained with long TR (20s), 4 averages, and 250 μs long rectangular excitation pulses, which were optimized for high signal reception. The measurement parameters were set identical for both field strengths. The full-width at half maximum (FWHM) of PCr was determined in unfiltered spectra. The SNR was calculated in frequency domain after applying a matched exponential filter. The effect of differences in coil quality factors was taken into account as described by Beuf et al. [4].

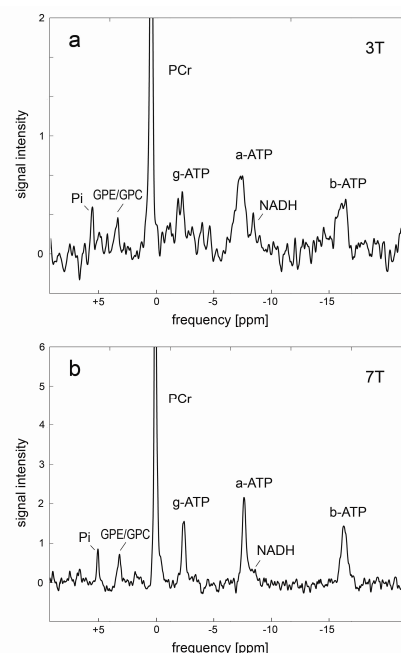


Fig. 2: sample spectra of ISIS localized single voxel ^{31}P -MRS with a voxel size of $2.5 \times 2.5 \times 2.5 \text{ cm}^3$ (=16ml). The SNR at 7T was ~ 3.2 times higher than at 3T for identical measurement parameters.

Results:

The coil quality factors were $Q_u=144$ and $Q_l=57$ at 3T, and $Q_u=180$ and $Q_l=70$ at 7T. Since the quality ratios are similar (2.57 and 2.53) for both field strengths, there should be no significant influence of the coils on the SNR difference. The SNR in the phantom obtained by surface coil localization at 7T (212 ± 25) was 2.1 times higher than at 3T (101 ± 15). This was similar to the difference in the calf muscle (7T – 68 ± 15 ; 3T – 35 ± 9 ; factor 1.9). The difference in SNR for the phantom spectra obtained by SV localization between 7T and 3T was similar (7T – 63 ± 12 ; 3T – 28 ± 6 ; factor 2.2), since T_1 of Pi was also similar (4.3 s and 4.5 s). *In vivo* ISIS localized spectra at 7T had the largest SNR difference compared to 3T (7T – 35 ± 3 ; 3T – 11 ± 1 ; factor 3.2). Of this, differences in T_1 of PCr [1] (4.0 s and 6.7 s) lead to a factor of 1.31 in SNR. The linewidth at 3T was $6.4 \pm 0.8 \text{ Hz}$ and $3.7 \pm 0.2 \text{ Hz}$, and at 7T $11.1 \pm 1.2 \text{ Hz}$ and $5.4 \pm 0.3 \text{ Hz}$ for surface coil localized and SV localized ^{31}P -MRS in the calf muscle, respectively.

Discussion and Conclusion:

Our results suggest that the difference in SNR of PCr that was found in previous studies by surface coil localized ^{31}P -MRS between 3T/4T vs 7T was significantly underestimated. In our study localized ^{31}P -MRS showed an ~ 3.2 times higher SNR at 7T than at 3T with identical measurement parameters, while surface coil localized ^{31}P -MRS showed only an increase by a factor of ~ 2 . Thus, the advantages of 7T compared to lower field strengths are larger for localized ^{31}P -MRS than previously reported.

References:

- [1] Bogner et al. MRM 2009; 62:574-582
- [2] Qiao et al. MRI 2006; 25:1281-1286
- [3] Bogner et al. ISMRM 2009
- [4] Beuf et al. MAGMA 2006; 19:202-208