31P-spectroscopy on humans at 9.4 T in combination with a patch antenna for proton imaging: Initial results

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Introduction: ^{31}P MR spectroscopy has the potential to observe the energy metabolism in the brain and other organs. Applications of this technique suffer, however, from the low MR sensitivity of the phosphorus nucleus, demanding long experimental durations and low spatial resolution. Measuring at ultra high field strength may help to overcome these limitations and to open the possibility to observe energy consumption at high spatial and temporal resolution. At 9.4 T, however, the need to provide the possibility for both phosphorus and proton acquisition, which is required for obtaining scout images and for shimming, makes the coil development challenging, since proton imaging at this field strength requires multi-channel transmit to avoid large voids in the proton images [1]. Here, the novel concept of traveling wave imaging is applied to obtain proton images, and combined with a surface or a birdcage ^{31}P coil. This setup is then used to obtain our first ^{31}P spectra from the calf muscles and the brain of healthy volunteers.

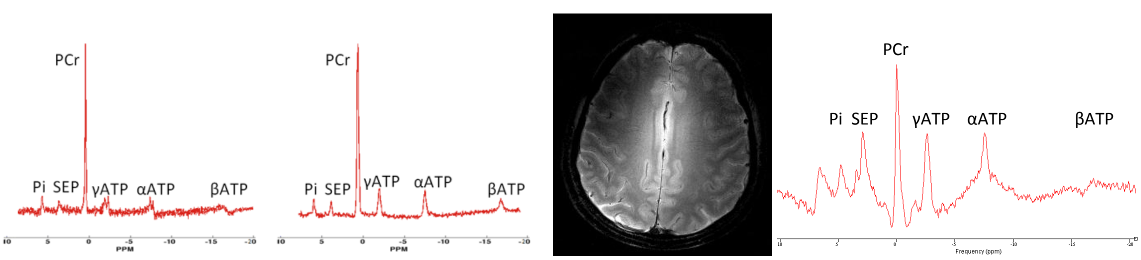
Methods: Experiments were performed on a 9.4 T human scanner (Siemens), equipped with a head only gradient insert with a diameter of 32 cm. For evaluation of the SNR obtained with ^{31}P spectroscopy at 9.4 T, a home-built quadrature surface coil, consisting of two rectangular loops (6 cm × 8 cm) was used to obtain global spectra from the calf of human volunteers. 16 averages were acquired within 8 s. For comparison with conventional field strengths, additional measurements were performed at 3 T, using a commercial ^{31}P/^{1}H surface coil (Rapid Biomedical, Germany). Here, a measurement of more than one minute was required to yield comparable SNR.

For brain spectroscopy, a sixteen-rung birdcage with a diameter of 25 cm was constructed. For proton imaging, a tunable patch antenna [2] was placed behind the subject. This antenna has a radiating patch of 21 cm diameter and was used for both transmission and reception at the proton frequency. To reach optimum sensitivity inside the relatively narrow head gradient, it was positioned very close to the subject. The antenna was used for shimming and for acquiring scout images. Global spectroscopy over the entire sensitive volume of the coil was performed within one minute, where a short acquisition delay of 0.35 ms was used to avoid signals losses in spite of the short T_2.

(a) (b) (c) (d)

Fig. 1: a) Quadrature surface coil for ^{31}P at 9.4 T (161.98MHz). b) double-tuned (^{1}H/^{31}P) surface coil for 3T studies (49.9MHz). c) ^{31}P Birdcage coil at 9.4 T. d) Patch Antenna for proton imaging at 9.4 T.

Results: The calf spectra a 9.4 T (Fig. 2a) showed, in spite of the much shorter acquisition duration, a significantly higher SNR than those acquired at 3 T (Fig. 2b): The SNR of the PCr-peak was increased by more than a factor of two at 8.5 times reduced scan time. In addition, the line splitting of the ATP multiplets disappears due to the field independence of J-coupling. The proton images acquired using the patch antenna have sufficient quality for localisation and shimming (Fig. 2c). First brain spectra using the birdcage coil for transmit and reception show promising SNR, in spite of the large volume of this coil (Fig. 2d).



(a) (b) (c) (d)

Fig. 2: a) global ^{31}P spectrum of the human calf at 3T (acquisition delay =0.15 ms, TR=1060 ms, Bandwidth=3 kHz, NA=64, scan time=1:08) b) global ^{31}P spectrum of the human calf at 9.4T (acquisition delay =0.23, TR= 500ms, Bandwidth=7 kHz, NA=16, scan time=0:08) with quadrature surface coil. c) Image acquired with the patch antenna for shimming and localization. d) Global ^{31}P spectrum of the human brain at 9.4 T (acquisition delay = 0.35, TR = 1000ms, Bandwidth=7 kHz, NA=64, scan time=1:07).

Discussion and Conclusions: Ultra high field is a promising possibility for ^{31}P spectroscopic studies with high spectral quality as well as spatial and temporal resolution. Taking advantage of the traveling wave concept makes it possible to obtain the necessary proton images for localization and shimming without having to combine the phosphorus coil with the highly complex transmit arrays necessary for ^{1}H imaging at 9.4 T. While the large diameter of the birdcage still poses limitations on transmit efficiency and receive sensitivity, first results show promising SNR and spectral quality.

References: [1] Shajan et al., MRM 66, 594–602 (2011); [2] Hoffmann et al, MRM, in press.