Uniform and broadband ^{31}P MRSI combined with ^{1}H MRSI in the human prostate using a double tuned quadrature endorectal coil

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Introduction: ^{1}H Magnetic resonance spectroscopic imaging (^{1}H MRSI) is useful for detection and staging of prostate cancer, using the changes in citrate (cit) and choline (cho) levels. While the choline resonance includes also choline-containing phospholipid metabolites, *in vitro* studies have shown that ratios rather than sum of these phospholipid metabolites can be more specific markers of prostate cancer aggressiveness. Using the SNR gain at 7T, these metabolites can be detected *in vivo* using ^{31}P MRS with an endorectal RF coil (ERC)[1]. However, with the endorectal RF coil as a ^{31}P transceiver, signal detection is non uniform and citrate and total choline cannot be detected.

In this study at 7T, we implemented a double tuned ERC as a quadrature ^{1}H transceiver and ^{31}P transceiver. As the T_1 values of the detectable phospholipids are similar, a progressive saturated pulse acquire sequence (i.e. short TR and optimized flip angle) was used to ensure a uniform and broadband detection of the phospholipid metabolites. Validated by phantom experiments, the detection of both ^{1}H and ^{31}P MR spectra in a patient with prostate cancer using the ^{1}H/^{31}P ERC has been demonstrated.

Materials and Methods: A 2-elements ERC (loop and stripline) tuned and matched both to ^{1}H (298.2 MHz) and the loop also to ^{31}P (120.6Mhz) (Fig. 1) is interfaced to a 7 tesla MR system (Philips, Best, the Netherlands) and filled with fluorinated fluid (GALDEN; Solvay Solexis, Milan, Italy). ^{1}H (2D MRSI (nsLASER [2], TE/TR=56/2000 ms, 24x8 matrix, 5x5x5 mm^3 voxel, acquisition time=7.46 min) and ^{31}P (3D MRSI (pulse acquire, TE/TR=0.42/200 ms, nominal flip angle=20°, 20x20x8 matrix, 12x12x12 mm^3 voxel, acquisition time=10.16 min) spectra were acquired. A phantom with PC as well as one patient (age: 66 with biopsy-proven prostate cancer (PSA: 8.6 ng/ml, Gleason score: 6) was scanned, after informed consent was obtained.

Results and Discussion: A uniform SNR detection over a 4 cm field of view was acquired by using an optimal flip angle for the block pulse, which was determined using simulations and validated in a phantom (Fig. 2). Although at the expense of SNR loss close to the coil, the SNR is maintained at depth, hence enabling exclusion of adiabatic and thus SAR demanding RF pulses. Consequently, the broadband excitation is obtained at very short TR. The phantom ^{31}P MRSI clearly shows the relatively uniform signal detection of phospholipid metabolites over 4cm while using the ERC.

The *in vivo* spectra (Fig. 3D/E) show individually distinguishable peaks of the following phospholipid metabolites, PE(6.7 ppm), PC (6.3 ppm), Pi (5.3 ppm), GPE (3.6 ppm),GPC (3.0 ppm, PCr (0 ppm), ATP's (-2.6, -7.6 and -16.2 ppm). Due to the short TR, optimal hamming weighting was applied providing minimal voxel bleeding of the surrounding muscle tissue (high PCr) (Fig 3B).

Next to this, ^{1}H MRSI was performed within the same scan session, visualizing choline (3.2 ppm), polyamines (3.1 ppm), creatine (3.0 ppm) and citrate (2.6 ppm) (Fig. 3C). Acquiring both ^{31}P and ^{1}H MRSI in prostate cancer may provide better determination of aggressiveness.

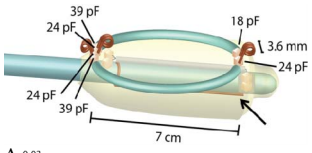

Figure 1: *Schematic overview of the double tuned quadrature endorectal coil, the arrow points out the stripline.*

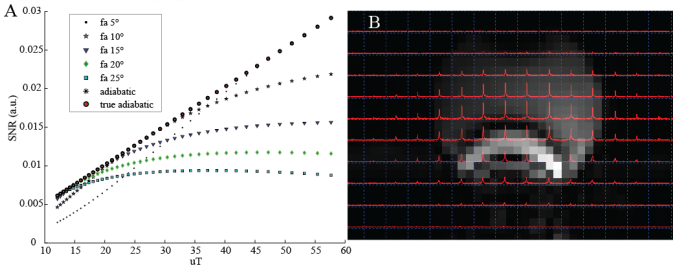

Figure 2: A) *Simulation of the signal-to-noise ratio in a non-uniform B_1 field for the block pulse with different flip angles and an adiabatic pulse assuming equal transmit and receive sensitivity for ^{31}P.* ***B)****^{31}P MRSI of a phantom containing only PC, in the background the black bands caused by the non-uniform B_1 field are visible. Due to the optimized flip angle (20° at 4cm depth) a relatively uniform signal detection has been obtained*

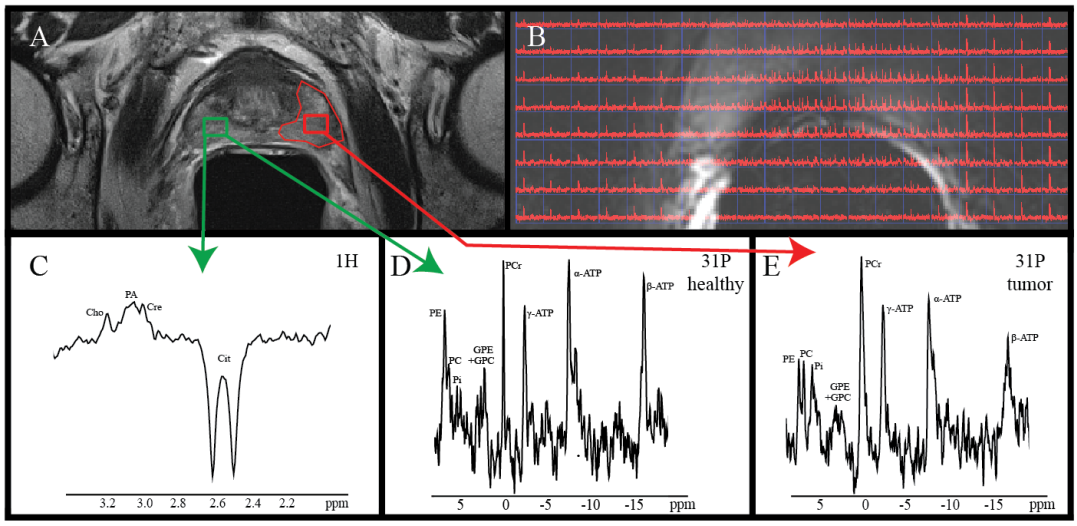

Figure 3: A) *T2w image of the prostate at 3T indicating the tumor area (red).*
B)*MRSI overlaid on T2w image of the prostate and surrounding muscles at 7T showing accurate spatial resolution of ^{31}P MRSI.*
C) *^{1}H spectrum of healthy area, choline (3.2 ppm), polyamines (3.1 ppm), creatine (3.0 ppm) and citrate (2.6 ppm)*
D) *^{31}P MR spectrum of healthy area,*
PE(6.7 ppm), PC (6.3 ppm), Pi (5.3 ppm), GPE (3.6 ppm),GPC (3.0 ppm, PCr (0 ppm), ATP's (-2.6, -7.6 and -16.2 ppm)
E) *^{31}P spectrum of tumor area, notice the changing ratio of PE/PC compared to the healthy spectrum*

Conclusion: ^{1}H MRSI and ^{31}P MRSI can be acquired in the human prostate at 7T within the same scan session, using a quadrature endorectal coil matched and tuned for ^{1}H and ^{31}P. Considering the similarities in T_1, relatively uniform signal detection of phospholipid metabolites can be obtained with the ERC incorporating a short TR and optimized flip angle with a high bandwidth.

References: *[1] Kobus, T. et al. Magn Res Med 2012. doi: 10.1002/mrm.24175 [2] Arteaga de Castro, C.S. et al. NMR Biomed 2012. doi: 10.1002/nbm.2881*