1H MR Spectroscopy of the human prostate using an adiabatic sequence with a SAR optimized endorectal RF coil

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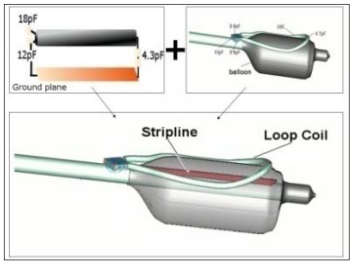
Objective: ^{1}H magnetic resonance spectroscopic imaging (MRSI) of the prostate is known to give information of metabolites like choline, creatine and citrate which can be used as biomarkers for monitoring tumor tissue. At higher magnetic fields, spectral resolution increases, which enables distinct detection of polyamines as has been shown using a semi LASER sequence combined with an endorectal RF loop coil by Klomp et al. (*NMR* Biomed. 2009;**22**: 495-501). However, with such single channel setup, substantial asymmetric B_1^+ versus B_1^- fields are obtained resulting in suboptimal detection. In addition, the absence of a full LASER due to SAR restrictions may contribute to additional signal losses considering the substantial non uniform B_1 field of the setup. Therefore, we propose the use of a two channel SAR optimized endorectal RF coil setup, which gives 4-fold reduced SAR per unit of B_1. With this setup we have obtained MRSI data of prostate cancer in vivo using a fully adiabatic optimized LASER sequence at 7T.



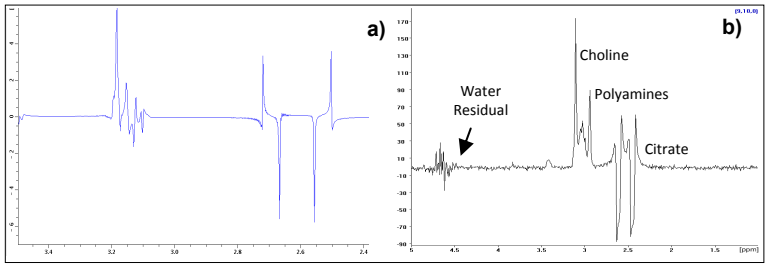


Figure 1 (left): dual channel endorectal RF coil, consisting of loop positioned on top of balloon containing a shortened stripline.

Figure 2 (center-right): a) Quantum mechanical simulation of citrate and b) phantom result showing same citrate behavior with very good water and fat suppression.

Materials/Methods: A dual channel endorectal RF coil was designed as illustrated in figure 1. Finite difference time domain calculations were performed to estimate the local SAR of the loop coil versus the combined coil setup and verified using temperature measurements in phantoms. Gradient echo images were obtained in phantoms and patients using two independent receivers to illustrate FOV of each coil element. Quantum mechanical simulations were applied to set the interpulse timings of the LASER sequence for obtaining maximum absorptive signal of the strongly coupled spin system of citrate, and validated using phantom measurements as shown in figure 2. Three prostate cancer patients with biopsy proven tumors (PSA 11.6-56.3) were positioned in the 7T MR system (Philips) in supine position with our in-house built two-element endorectal coil. Two of these patients were under hormone therapy. T2 weighted turbo spin echo (TSE) images were obtained for anatomy and tumor localization (TR=5s, 312x306 matrix, 25x25x8.6cm FOV, 8 slices 2mm thick). Single voxel (SV) (LASER, TR=2s, 15x15x15mm voxel, 64 averages) and 3D chemical shift imaging (CSI) (TR=2s, 6x6x6 matrix, 36x36x36xmm FOV) measurements were acquired.

Results/Discussion: Comparing a loop coil with the two-element setup we show it is possible to obtain more symmetric B_1^+ versus B_1^- field patterns (Fig. 3c). In addition a 4-fold SAR reduction was found per unit of averaged B_1 in the prostate as shown in figure 3. Therefore, this setup allows the use of the full adiabatic sequence within SAR limits. Interpulse timings were optimized for maximum signal of the strongly coupled spin system of citrate, figure 4. Spectroscopy results in-vivo at 7T are shown for two patients in figure 5 illustrating the ability to detect choline, creatine, polyamines and citrate levels.

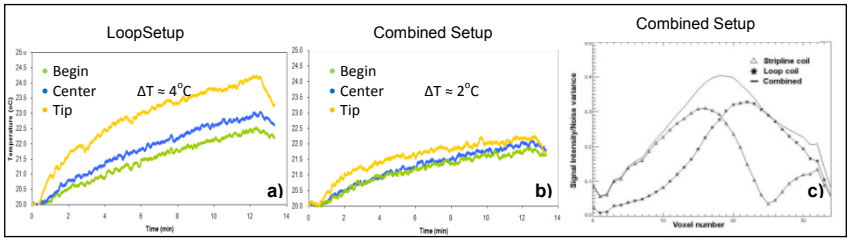


Figure 3: Phantom temperature measurements with a) conventional and b) combined endorectal RF coil at 400% SAR. Combined setup has half of the temperature increase at same power and c) when elements are combined an extra √2 B_1 can be obtained.

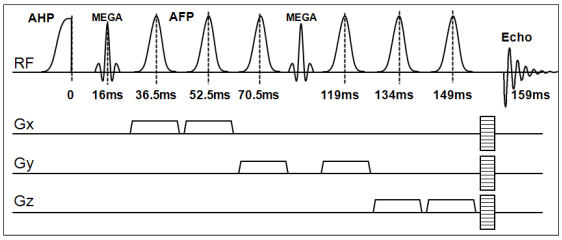
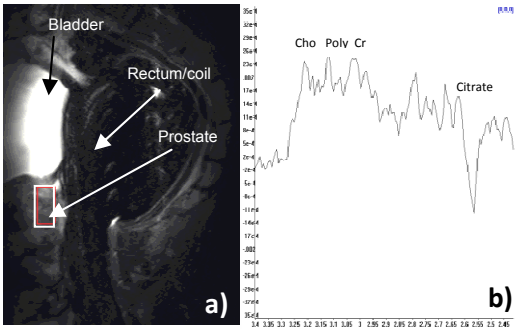
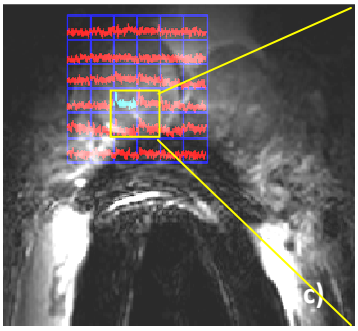


Figure 4: Pulse scheme for the LASER sequence optimized for the maximum detection of citrate at 7T, including MEGA pulses for water and lipid suppression.





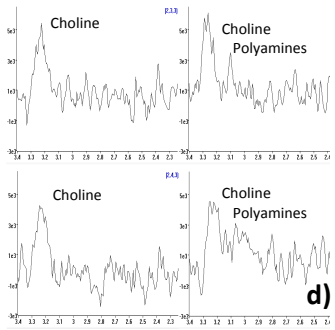


Figure 5: MR spectra obtained from patients with prostate cancer, both in SV in a), b) and in 3D CSI c), d). Choline, polyamines, creatine and citrate levels can be seen.

Conclusions: Prostate ^{1}H MRSI at 7T can be obtained with fully adiabatic sequences using SAR optimized endorectal RF coils. With this setup, choline, polyamines, creatine and citrate levels could be depicted in prostate cancer patients.