Proton Spectroscopic Imaging of the Human Prostate *in Vivo* at 7T

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Introduction

To meet the demand for a better sensitivity in ^{1}H MRSI of the prostate, the higher field of 7T may be employed. With the increased SNR from higher field strengths, the spatial resolution of the MRSI method can be increased leading to reduced partial volume effects. In addition, the higher spectral chemical shift dispersion may not only improve the accuracy of determining the contents of choline and citrate, but may also enable the separation of polyamine signals from creatine. At 7T some challenges need to be addressed. First of all, to obtain a chemical shift displacement artefact at 7T comparable to 3T, the bandwidth of the slice selective RF pulses needs to be 2.3 times larger. This requires a 2.3 times larger B_1 field when using the same optimized RF envelopes of the PRESS sequence. Secondly, the B_1 fields are inhomogeneous, which excludes the use of SLR optimized refocusing pulses for accurate slice profiles. Thirdly, as the MRSI method includes high bandwidth refocusing pulses, the RF power deposition can reach the limits in safety guidelines easily. Finally, as citrate has a strongly coupled spin system, the timing interval between the RF pulses needs to be optimized for maximum absorptive signal. Here we present an approach involving a transmit receive endorectal coil in combination with an MRSI method that includes adiabatic slice selective refocusing pulses, for optimal detection of the strongly coupled spin system of citrate in the prostate at 7T. Quantum mechanical simulations, phantom and in vivo measurements were used to validate the MRSI method. Finite Integration Technique (FIT) calculations at a detailed human prostate model as well as temperature measurements in phantoms, and in vivo were performed to assure compliance with safety guidelines.

Methods

The mechanical housing and conductors (3.5cm x 7cm) of a 3T endorectal probe (Medrad) were used and matched to 50Ω at 297MHz. The coil was interfaced to a 7T whole body MR system (Siemens, Erlangen) using a home build TxRx switch with a noise figure of less than 1dB. SAR calculations were performed using the FIT method at a human prostate model derived from high resolution MRI data. In addition, MR thermometry is performed on a gel phantom to locate the hot spot. The in vivo temperature in the human prostate was measured using a fibre optic thermometer.

The MRSI method with adiabatic slice selective refocusing pulses (semi LASER [1]) was used with inter pulse delays optimized for absorptive citrate signal using quantum mechanical simulations. The adiabaticity and bandwidth of the RF pulses were calculated using the Bloch equations. In addition, two dual chemical shift selective refocusing pulses were added for MEGA [2] water and lipid suppression. The MRSI sequence (Fig. 1) was used to obtain data from a healthy volunteer using the endorectal coil as a transceiver at RF power levels that remain within safety guidelines.

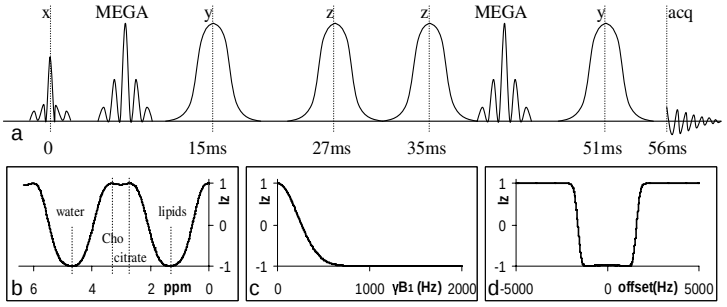

Fig. 1: RF pulse sequence of semi LASER with MEGA optimized for citrate detection (a) including the frequency (b,d) and B_1 profiles (c) of the pulses.

Results

The required RF power for a 1ms rectangular 180-degree pulse using the endorectal coil at a distance of 3cm from the conductors is less than 35W. Using the MRSI sequence at a TR of 1s (i.e. at an average power of 0.76W) a maximum temperature increase of less than 1° Celsius was obtained in vivo close to the capacitors (Fig. 2). In this sequence, the bandwidth of the adiabatic slice selective refocusing pulses is 3.2kHz (Fig. 1d), which minimizes the chemical shift artefact to 6% between choline and citrate resonances. The optimized timing from quantum mechanical simulations resulted in an echo time of 56ms with absorptive citrate spectra in MRSI measurements of the human prostate in vivo (Fig. 3). Although high SNR data was obtained at a nominal voxel size of (4mm)^3, good MR spectra can still be obtained in the human prostate at a resolution of nominally (3mm)^3, within 8.5 min. (Fig. 3, right).

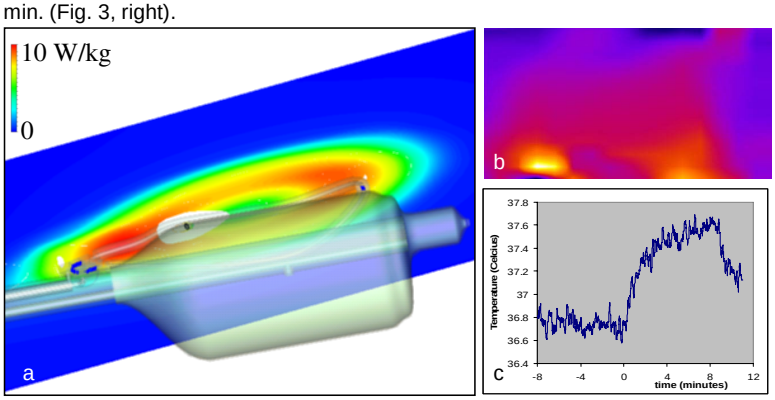

Fig. 2: Safety validation of the endorectal RF coil as a transmitter. (a) SAR modeling; (b) MR thermometry of a phantom; (c) in vivo temperature at hot spot

Conclusion and discussion

These results indicate that a transmit/receive endorectal coil can be used safely for 7T at a maximum averaged RF power of 0.76W. Within these RF power constrains, an MRSI sequence with adiabatic slice selective refocusing pulses can be applied and optimized for citrate detection with a chemical shift artefact of only 6%. Clear resonances of choline, polyamines, creatine and citrate can be detected in human prostate at a spatial resolution down to (3mm)^3.

References

1 Scheenen T et al. MRM In press; 2 Mescher M et al. JMR 1996; 123:226-229.

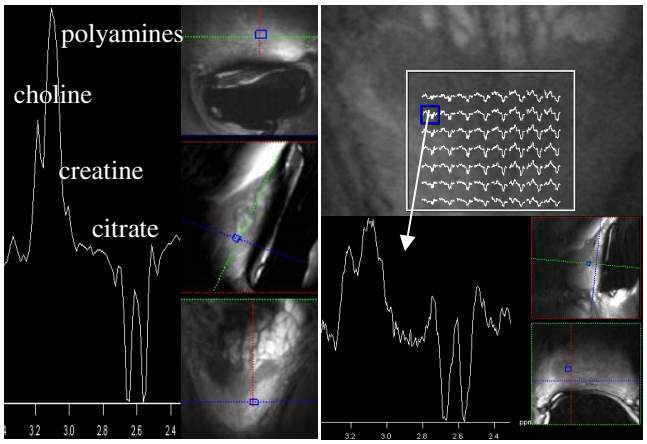

Fig. 3: MRSI of the prostate at 7T of a healthy volunteer clearly showing resonances of citrate, choline, creatine and polyamines at nominal voxel sizes down to (3 mm)^3. A slice from the 3D MRSI dataset, obtained at high spatial and temporal (8.5 minutes) resolution is shown together with a MR spectrum of one individual voxel (left). A voxel from the 3D MRSI dataset obtained in the same volunteer at a larger nominal voxel size of (4 mm)^3 and acquisition time of 15 minutes shows the signals at high SNR (right).