Towards MRSI of the prostate at 7T using adiabatic RF pulses and a transmit and receive endorectal coil

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Introduction

MR systems operating at 7T are increasingly being introduced for human investigations. Although the entire human body fits inside the magnet of these systems, results are mostly obtained from the brain only. This is mainly because whole body spin excitation requires complicated RF coil technology, and may require a lengthy procedure for RF shimming of a region of interest. Even in the presence of an RF shimmed region in the human body, local RF heating will limit the use of many sequences conventionally applied at lower field strengths. To meet the demand for a better sensitivity in ^{1}H MRSI of the prostate the higher field of 7T may be employed, but this requires the use of a sufficiently fast and safe acquisition method, in particular for optimal detection of citrate and choline resonances. Here we present an approach involving a transmit receive endorectal coil in combination with an MRSI method that includes adiabatic slice selective refocussing pulses, for optimal detection of choline signals and the strongly coupled spin system of citrate in the prostate at 7T. Quantum mechanical simulations and phantom measurements were used to validate MRSI methods, and ex vivo measurements were performed to assure compliance with SAR guidelines.

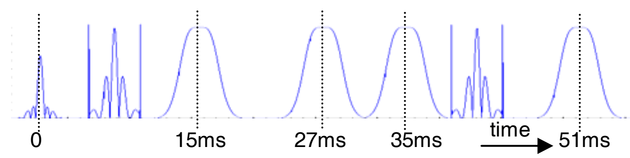

Fig. 1: RF Pulse sequence of semi LASER sequence with MEGA water and lipid suppression, optimized for citrate detection. Note the large RF duty-cycle of this sequence.

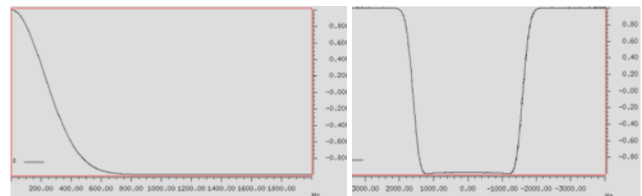

Fig. 2: RF (left) and frequency (right) profile of the refocusing pulses, showing adiabatic condition (γB_1>600Hz) and a sharp slice profile at a bandwidth of 3.2kHz.

Methods

The mechanical housing and conductors (4cm x 8cm) of a 3T endorectal probe (Medrad) was used and matched to 50 ohm at 297MHz for full tissue load, using a total of 4 capacitors with equal mechanical dimensions as those used for 3T. 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. Temperature measurements on a filet of chicken tightened to the coil were performed at the locations closest to the capacitors during a 6-minute MR sequence at 1.7W of averaged RF power. The efficiency of the coil was determined using a conventional spin echo sequence applied on the same load. We used an MRSI method with adiabatic slice selective refocusing pulses that compensate for inhomogeneous B1 fields (semi LASER [1,2]). The adiabaticity and bandwidth of the RF pulses were calculated using the Bloch equations. The time delays in the sequence were adjusted for an optimal line-shape of the strongly coupled spin system of citrate using quantum mechanical simulations (Qsim [3]). In addition, two dual chemical shift selective refocusing pulses were added for MEGA [4] water and lipid suppression. The time optimized semi LASER sequence with MEGA water and lipid suppression (figure 1) was used to obtain MRSI data from a phantom (sphere containing citrate, choline and creatine, surrounded by oil) using the endorectal coil as a transmitter and receiver. Power determination for the phantom measurement was extrapolated to SAR values for in vivo use, taking the efficiency of the coil at tissue load into consideration.

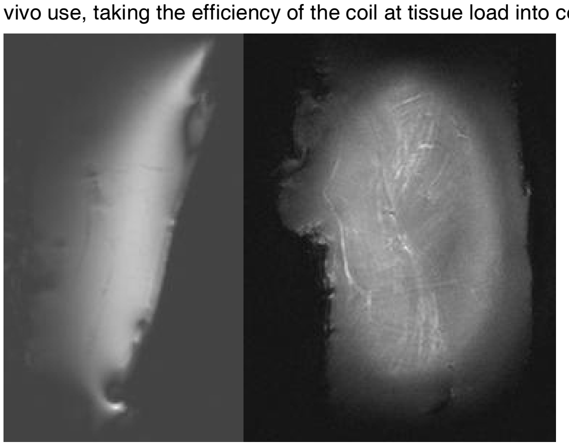

Fig. 3: Sagital and coronal spin echo images of a filet of chicken obtained with the endorectal coil as transceiver

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 50W (fig 3). At an average power of 1.7W for duration of 6 minutes, a maximum temperature increase of 1.5 degrees Celsius was obtained close to the capacitors. The average power of the semi LASER sequence with MEGA water and lipid suppression scaled to full tissue load is 1.1W for a TR of 1s. In this sequence, the bandwidth of the adiabatic slice selective refocusing pulses is 3.2kHz (fig 2.), 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, which agrees with phantom measurements (Fig 3).

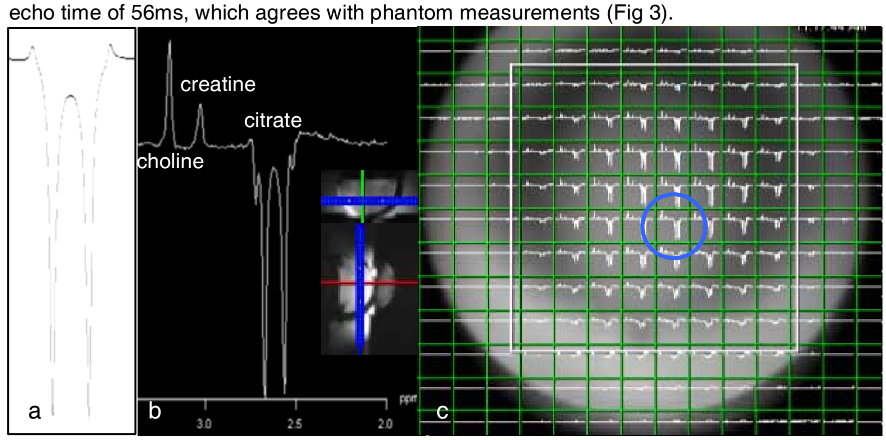

Fig. 3: MR spectra (a. simulated, b. measured) of citrate, choline and creatine using the semi LASER sequence with MEGA water and lipid suppression. The spectral map (c.) obtained with the MRSI method shows apart from a minimum chemical shift artifact, no contamination outside the excited volume indicating proper functioning of adiabatic slice selections.

Conclusion and discussion

These preliminary results indicate that a transmit and receive endorectal coil can be used safely for 7T (i.e. less than 1 degree temperature increase) at a maximum averaged RF power of 1.1W. Within these RF power constrains, an MRSI sequence with adiabatic slice selective refocusing pulses can be applied and optimized for choline and citrate detection with a chemical shift artefact of only 6%. Thus the conditions of this approach allow its application *in vivo*.

References

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