^{1}H MR spectroscopic imaging of the prostate at 7T using spectral-spatial pulses

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Introduction: ^{1}H MR spectroscopic imaging (MRSI) can be used as part of a multiparametric MRI prostate examination at 1.5 or 3T in prostate cancer (PCa) management[1]. PCa probed by ^{1}H-MRSI usually expresses decreased citrate (Cit) and spermine (Spm) and elevated choline (Cho) levels compared with normal prostate tissue[2]. The most common localization method for prostate ^{1}H-MRSI is PRESS, with additional dual-frequency selective pulses for lipid and water suppression, and outer volume saturation slabs placed around the prostate to decrease lipid signals[2]. At 7T with endorectal transceiver coils, the trend is towards semi or nonselective LASER pulse sequences with conventional dual-frequency selective pulses[3,4]. A viable alternative with the increased chemical shift separation at 7T is to only refocus the signals of interest, rather than suppressing unwanted signals from water and lipids. B_1 shimming of an external transmit (Tx) array coil combined with a receive (Rx) endorectal coil (ERC) allows the use of spectral-spatial (SPSP) pulses to localize only the signals of interest, providing a significant reduction in SAR compared to LASER sequences. In this work we assessed the feasibility of prostate ^{1}H-MRSI using SPSP pulses at 7T.

Methods: A linear-phase SPSP pulse for refocusing was designed in Matlab[5,6]. The pulse length was 35.2 ms, with a 1ppm wide pass band and transition bands of 0.3ppm. Variable rate selective excitation (VERSE) was used to reduce RF peak power requirements. The new double spin-echo sequence consisted of an 8ms minimum-phase slice-selective excitation pulse, followed by two SPSP refocusing pulses. Crusher gradients were positioned around the SPSP pulses. Sequence timing was optimized to obtain maximum Cit signal intensity resulting in TE=135ms. Phantom and patient experiments were performed on a 7T whole body MR system (Magnetom, Siemens, Erlangen). A ^{1}H R_X ERC was used in combination with an 8-channel external ^{1}H T_X/R_X body array coil. The B_0 homogeneity in the prostate was optimized using 3D phasemap shimming. B_1^+-phase shimming maximized ^{1}H amplitude in the prostate, the flip angle was calibrated[7] and an absolute B_1 map was acquired[8]. During MRSI, only the ERC was used for signal reception. The sensitivity of the sequence to B_0 and B_1 inhomogeneities was evaluated in a phantom (fig. 2). ^{1}H-MRSI using SPSP pulses was acquired in two patients with no visible PCa lesions (at 3T mpMRI, TRUS Gleason scores 3+3). The VOI size was adjusted to the prostate dimensions, minimum size of the SPSP directions was 50 mm. Voxel size was 0.64cc, TR=1s, TA=4:21min. T_2-weighted TSE images (TR=4.4s, TE=80ms) were recorded to provide an anatomical background for the MRSI measurements. All measurements were performed within SAR limits.

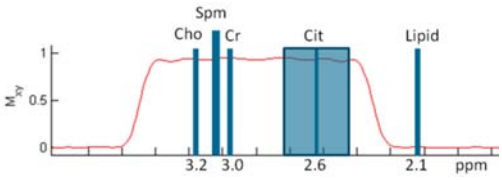

Fig. 1 Spectral selectivity of SPSP pulse. Cho: choline, Spm: spermine, Cr: creatine, Cit: citrate

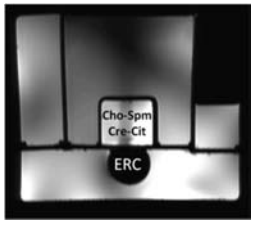

Fig. 2 Prostate phantom with sugar solution in outside containers to load 8-ch array coil.

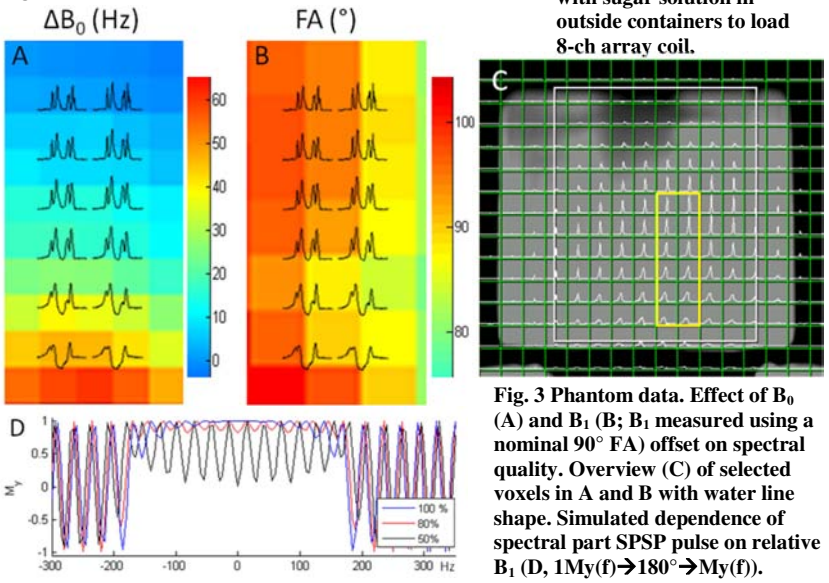

Fig. 3 Phantom data. Effect of B_0 (A) and B_1 (B; B_1 measured using a nominal 90° FA) offset on spectral quality. Overview (C) of selected voxels in A and B with water line shape. Simulated dependence of spectral part SPSP pulse on relative B_1 (D, 1My(f)→180°→My(f)).

Results: The ^{1}H spectra were well localized within the VOI in both phantom and patient data. In the phantom data, the spectral shape varied with deviations in B_0 (fig. 3AC). Small variations in ratios between the metabolite peaks are probably mainly caused by B_1 inhomogeneities (fig. 3BD). Negligible water signal was present in the spectra; however, lipid signal was excited at the edge of the prostate in 1 patient which was not directly related to a deviating B0 shim (fig. 4). Spm signal was high in all prostate spectra concealing Cre in most spectra.

Discussion: The increased SNR and spectral dispersion at 7T could be exploited for prostate ^{1}H-MRSI; however RF power deposition becomes an issue if a Tx/Rx ERC is used, requiring a sequence with adiabatic pulses[3]. The Tx array in combination with B_1 shimming allowed the use of non-adiabatic SPSP pulses to perform prostate ^{1}H-MRSI, and the Rx ERC ensured local sensitivity within the prostate. Although water and lipids might have been excited somewhere in the abdomen due to local shim variations, no spurious signals from outside the FOV were detected in the spectra because of the limited sensitivity profile of the ERC. A homogeneous B_0 and B_1 shim within the whole prostate is essential to obtain correct metabolite signals. Changes in spermine signal in PCa might be readily detected with this sequence. We could not confirm this in the measured patients however, since they did not present with visible PCa lesions.

Conclusion: Separating Tx and Rx for good prostate imaging at 7T also enabled ^{1}H-MRSI using SPSP pulses. Well-resolved in vivo prostate spectra were obtained with this low SAR sequence. Spectral changes in PCa should be investigated in a larger patient cohort.

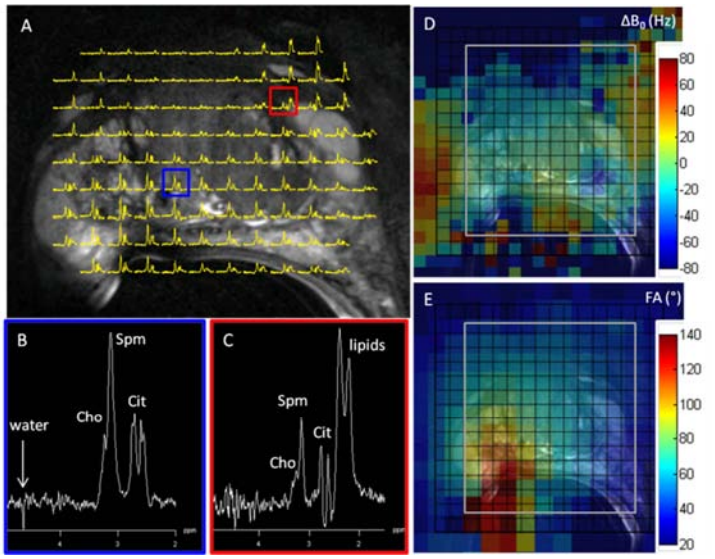

Fig. 4 Patient data. A: spectral map on top of T2W 7T prostate image, some lipid signal at edges of the prostate. B: spectrum with resolved Cho, Spm and Cit, no water residual. C: lipid contamination. D: B_0 map. E: Flip angle map, measured using a nominal 90° FA.

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Acknowledgements: ERC Grant agreement n° [243115]