# Three Dimensional Spectroscopic Imaging in the Prostate with a Surface Combined Endorectal Coil at 7 Tesla

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**INTRODUCTION:** The benefits of performing prostate spectroscopy at 7T include increased spectral and spatial resolution. The potential exists to be able to better quantify individual metabolites, localize smaller volumes of disease and better monitor disease progression or treatment response. However, spectroscopy in the body at 7T faces many challenges including the well described destructive interferences reducing both RF homogeneity and efficiency, increased susceptibility and chemical shift artifacts and an increased concern over local rather than global specific absorption rates (SAR) which would be responsible for local heating. Prostate spectroscopy at 7T has currently been demonstrated through the use of a single-loop transceiver endorectal coil (1). The advantage of such coils are the promise of high SNR on receive and high transmit B1 (B1+), at least close to the prostate, and improved prostate stability and B0 homogeneity as a balloon in the coil is typical inflated with susceptibility matching fluid. Other studies have demonstrated that SAR constraints combined with low achievable B1+ in the prostate limit the applicability of an 8 channel transceiver surface array coil for spectroscopy in the prostate (2). While local SAR is still a limiting factor, we demonstrate that full 3D spectroscopic imaging can be achieved with a surface transmit coil at 7T. To realize the full potential of 7T with respect to SNR, this surface array is combined with a receive-only ERC on reception.

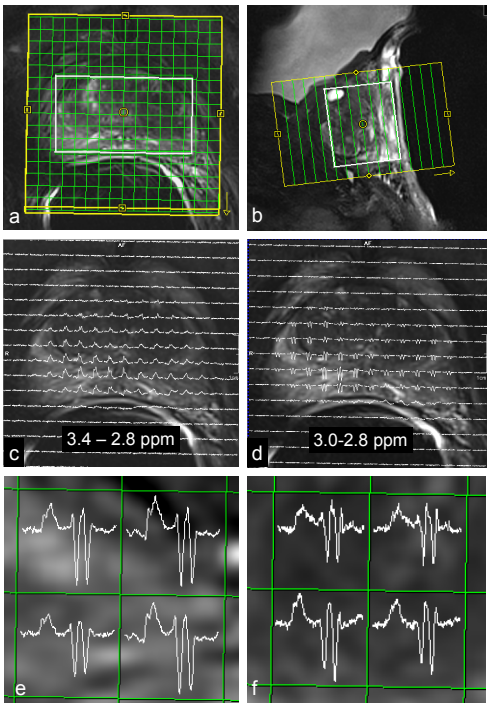


**Figure 1:** 3DSI results at a TE of 145 ms.

**METHODS:** The MRI system used for this study included a Magnex 7T, 90cm bore magnet with Siemens console and whole body gradients. An external 16-channel TEM stripline array was used for both transmit and receive. A series of 16, 1 kW amplifiers with independent phase and gain control (CPC, Pittsburgh, PA) were used to power the surface array coil and were optimized for transmit efficiency in the region of the prostate (3). Power monitoring on each channel was accomplished using a homebuilt system (4). On receive, a previously described receive-only ERC was used in combination with the surface array (4).

Healthy subjects were imaged under and IRB approved protocol. Anatomic scout T2w turbo spin echo (TSE) images were acquired to visualize critical structures and for planning spectroscopy (TR 3500 ms, TE 130 ms, turbo factor 9, resolution 0.5x0.5x3.0 mm3). The 3DSI protocol volume was acquired perpendicular to the rectum as shown in Fig. 1a and 1b. Localization was achieved by using semi-LASER (5) which uses a standard excitation pulse for volume localization in one plane and two pairs of adiabatic refocusing pulses in the other two orthogonal directions. Sequence parameters included (TR/TE 2000/145 ms, 16x16 acquisition matrix, 8 slices, 4000 Hz bandwidth, 4 weighted averages, acquired voxel resolution of 0.4x0.4x0.5 $mm^3$). Water suppression was accomplished with VAPOR (6) in combination with MEGA, the later of which also provided lipid suppression (7). All localization pulses used a center frequency offset to 2.9 ppm to minimize the chemical shift displacement of the target region for the metabolites of interest from choline at 3.2 ppm to citrate at 2.6 ppm. The

Power calibration was based on maximizing the integral of the water peak using a single voxel experiment and incrementing the excitation power. Power deposition was limited to levels determined by the IEC standard 60601-2-33 and were based on FDTD modeling of the external transmit coil. Previous simulations and experimental results have shown that receive-only ERC coil is not the limiting factor with respect to the applied RF, but rather, it is the local SAR close to the transmit elements (4). Localized B0 shimming was performed within the selected volume of interest for spectroscopy using volumetric phase maps (12)

**RESULTS:** Results from a 3DSI semi-LASER acquisition are shown in Fig 1 c-f. The localization and coverage of the CSI data through the middle slice of the data is shown in the ranges of 3.4-2.8 ppm and 3.0-2.2 ppm in Fig 1c and 1d respectively. Fig 1e and 1f show for spectra from the peripheral zone from the right middle slice and the left basal slice respectively. Even though the spectra in Fig 1f are obtained from the edge of the localized volume and on the least sensitive side of the ERC good spectral quality is maintained. The final linewidth of water after localized shimming was 21 Hz in this example.

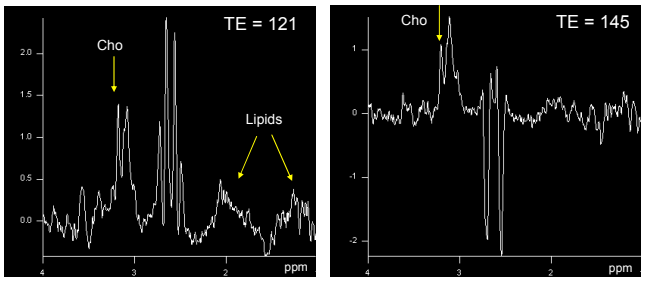


**Figure 2:** Spectra obtained with the same acquisition strategy at echo times of 121 (left) and 145 (right) ms.

**DISCUSSION:**

Homogenetity of RF is fairly high on transmit with the local B1+ shimming methods used. Despite a relatively homogeneous B1+, the available peak B1+ is low resulting in low bandwidths for typical RF pulses. Along with being B1+ insensitive adiabatic pulses can be long while maintain large bandwidth and excellent pulse profiles. The bandwidth of the pulse in this case was 1 kHz resulting in a chemical shift displacement of 9% over 0.3 ppm. Despite the absence of outer volume suppression and large volume of coverage, the MEGA lipid suppression provided sufficient lipid suppression throughout the spectroscopy volume. However, it can be observed that with reduced echo times the residual lipid signal is more prevalent even as observed with an echo time of 121 ms (Fig 2). Other observations related to echo time are that choline is disproportionately effected by the increase in TE and the ability to differentiate choline from the polyamine resonances are qualitatively unaffected by varying evolution times of the strongly coupled spin system. However, it very well may be decreases in choline at TE 145 might be partially due to out of phase or decreased in-phase contributions of the polyamine resonances. The challenge with using the external surface array is its decreasing performance with subject size. While this protocol has performed well in multiple subject both with and without the ERC, methods to reduce local SAR would be advantageous as the TR was required to be above the minimum to keep power deposition below allowed limits. Currently acquiring data with a volume of 80 mL which is about what is expected compared to 3T with an ERC (i.e. 0.5x0.6x0.6 mm3 = 180 uL), however a rigorous evaluation of SNR still needs to be performed once hardware and acquisition parameters are finalized.

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