

# First steps towards multiparametric prostate MRI at 7T

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## Introduction

Multiparametric MRI (mpMRI) is an important tool in prostate cancer (PCa) management. Recommended mpMRI protocols consist of high-resolution T2-weighted (T2w) imaging, diffusion weighted imaging (DWI), and proton spectroscopic imaging (<sup>1</sup>H-MRSI) or dynamic contrast enhanced (DCE) imaging. An important issue in localized PCa is a non-invasive assessment of tumor aggressiveness to select patients eligible for active surveillance, to direct biopsies, or to guide therapeutic interventions. ADC values and metabolite ratios obtained from <sup>1</sup>H-MRSI at 3T have been shown to correlate with tumor Gleason Scores (GS), but considerable overlap between tumor aggressiveness categories remains<sup>1,2</sup>. Increasing the magnetic field to 7T can lead to improved SNR in both imaging and MRSI, but is especially beneficial for MRSI due to the improved peak separation at higher fields. Moreover, 7T offers potential for use of new biomarkers in <sup>31</sup>P-MRSI<sup>3</sup>. 7T imaging of the abdomen is an emerging field, facing challenges including strong RF inhomogeneity, high specific absorption rates (SAR) and increased sensitivity to off-resonance effects. The feasibility of T2w prostate imaging at 7T has been demonstrated previously<sup>4,5</sup>. RF shimming with an external 8 channel transmit array also creates possibilities for DWI and simplified <sup>1</sup>H-MRSI, which combination we present here as the first steps towards a full multiparametric MRI protocol for prostate at 7T.

## Methods

Two patients with biopsy-proven PCa (ages 67 and 70, PSA 1.7 and 6.3, Gleason scores (GS) 3+3=6 for both) were included. Peristalsis was suppressed by intramuscular injection of 1 mg glucagon and 20 mg butylscopolaminebromide. All imaging was performed on a 7T whole body system (Magnetom, Siemens Healthcare, Erlangen), using an external 8 channel flexible body array coil<sup>6</sup> for transmission and an endorectal coil (ERC) filled with perfluorocarbon for signal reception. High-resolution T2w imaging was performed in transverse and sagittal directions using a turbo spin-echo (TSE) sequence<sup>5</sup> (TR/TE 4380/80, resolution 0.3x0.3x2 mm, 12-20 slices, TA 2:17 min). DWI was performed using 5-shot readout-segmented EPI<sup>7</sup> at b-values of 0, 100, 400 and 800 s/mm<sup>2</sup> (TR/TE 3300/49 ms, FOV 130x130 mm, resolution 1.4x1.4x2 mm, 3 diffusion directions per b-value, 1 average, acceleration factor 2, TA 3:28 minutes). ADC maps were generated using all b-values except b=0 s/mm<sup>2</sup>. <sup>1</sup>H MRSI was performed using a PRESS sequence (TR/TE 1000/135 ms, TA 4:21 min) with slice selective excitation and 2 spectral-spatial (SPSP) refocusing pulses (spectral bandwidth 1 ppm)<sup>8</sup>. No additional water or lipid suppression was applied. The nominal MRSI voxel size was 6x6x6 mm<sup>3</sup>, corresponding to 0.64 cc after k-space apodization.

## Results

Both patients completed the protocol within 60 minutes. B<sub>0</sub> and RF shimming and flip angle calibration took 22 minutes on average. All exams were performed within SAR limits, and no adverse events occurred. Transverse and sagittal T2w imaging showed excellent image quality (Figs 1a,b and 2a,b). DWI showed good image quality and sufficient SNR at b-values up to 800 s/mm<sup>2</sup> at the spatial resolution used (Figs 1c,d and 2c). Image distortion was negligible. Although low, some ghosting artifacts were observed in the phase encoding direction, possibly due to eddy currents caused by the rapidly switching readout gradients (arrows in Figs 2c, d). ADC maps (Figs 1e, 2d) had good image quality throughout the prostate and showed similar anatomical structures as seen in T2w imaging, such as differences between peripheral zone and transition zone and BPH nodules (arrows in Figs 1a,e). MRSI showed well resolved resonances of Citrate (Cit), Spermine (Spm) and Choline (Cho) and excellent water and lipid suppression in areas with sufficiently good B<sub>0</sub> shim (Figs 1f, g). Broadened line shapes and lipid contamination were observed in areas with deteriorated B<sub>0</sub> or RF shims (Fig 1h).

## Discussion

Following the clinical concept of using separate coils for transmitting and receiving the MR signal allowed creating homogeneous flip angle distributions in the prostate region by B<sub>1</sub> shimming, while taking full advantage of the increased SNR at 7T with the ERC. Furthermore, using only the ERC for signal reception allowed reducing the FOV without causing fold-in artifacts. This resulted in very high resolution T2w images acquired in less than 2.5 minutes. For DWI, the readout-segmented EPI sequence allowed substantial shortening of the EPI echo train, reducing TE and maximizing SNR, and simultaneously reducing susceptibility artefacts, minimizing distortion. For MRSI, using SPSP refocusing pulses and receiving with the ERC only can result in very good water and lipid suppression in some prostate regions, but is sensitive to off-resonance effects, requiring good B<sub>0</sub> and RF shims. The SNR markedly decreased away from the ERC, but was still sufficient for T2w imaging and DWI at the anterior aspect of the prostate, even for the large prostate shown in Fig 2 (prostate size in AP direction: 56 mm).

## Conclusions

High resolution anatomical prostate imaging, DWI and <sup>1</sup>H-MRSI can be performed at 7T in a single exam. 7T imaging offers unprecedented spatial resolutions in T2w imaging and DWI of the human prostate, and offers potential for high quality 1H-MRSI within short acquisition times.

## References

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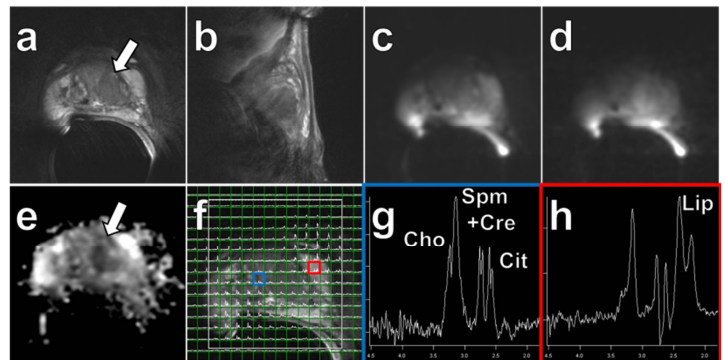


Fig. 1: High resolution transverse (a) and sagittal (b) T2w imaging, DWI at b=0 s/mm<sup>2</sup> (c) and 800 s/mm<sup>2</sup> (d), ADC map (e), and <sup>1</sup>H MRSI spectral map (f) in a 67 y.o. PCa patient (GS 3+3). High-quality spectra (g, blue outline in f) show contributions from Citrate, Spermine + Creatine and Choline. Other spectra exhibit lipid contamination (h, red outline in f).

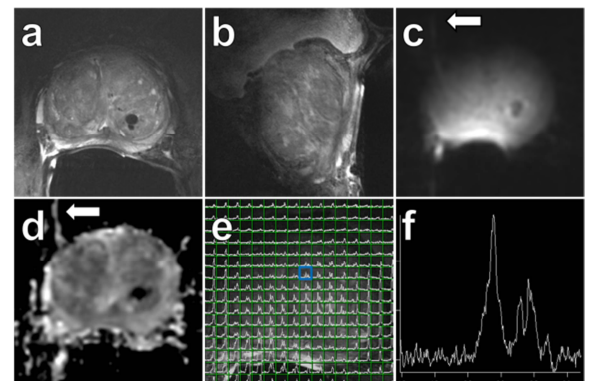


Fig. 2: High resolution transverse (a) and sagittal (b) T2w imaging, DWI at b=800 s/mm<sup>2</sup> (c) and ADC map (d), spectral map (e) in a 70 y.o. PCa patient (GS 3+3). The spectrum of the voxel outlined in blue in (e) is shown in (f).