**Clinical Cancer MRI: Case-based**

**New Horizons: Applications of 7T in Cancer**, *with a focus on prostate cancer*

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## Highlights

- **With dedicated coil setups challenges of prostate imaging at 7T have been largely overcome**
- **Use of 7T enables detection of $^{31}$P signals in the prostate as potential new useful biomarkers**

## MR spectroscopy and imaging of the prostate at 7T

The use of MR imaging and functional MR techniques in the management of prostate cancer has gradually gained importance during the last decade. Already in the late nineties it was recognized that the excellent soft tissue contrast provided by MR could be beneficial in assessing prostate abnormalities (1). Nowadays prostate MR consist of a multi-parametric MR examination combining, next to conventional anatomic T2W MR imaging, functional MR techniques such as diffusion-weighted imaging (DWI), dynamic contrast-enhanced MR imaging (DCE-MRI) and proton MR spectroscopic imaging ($^{1}$H-MRSI).

The step from 1.5 to 3 Tesla largely increased the number of opportunities for prostate MR and opened up the possibilities of multiparametric MRI for detection, localization, staging and risk stratification of prostate cancer (2). Increasing the magnetic field strength further may bring additional benefits in answering some of these clinical questions. Ultra high field MR is of particular interest for imaging and spectroscopy techniques that are SNR limited at the clinical field strengths of 1.5 or 3 Tesla, such as non-proton imaging and spectroscopy.

However, to be of any clinical value, anatomical prostate imaging with T2W-MRI should also be of good quality at ultra high field strengths, which is technically demanding. MR signal generation by the application of radiofrequency (RF) pulses over time at 7T is generally not limited by whole-body average (global) specific absorption rate (SAR) limits but rather by local SAR (3). The short RF-wavelength of the excitation and refocusing pulses leads to very significant flip angle and electric field variations, causing local hot-spots in SAR inside the body. Numerical computations of the RF field distribution and the corresponding SAR can be performed by using detailed computer-aided design models of the coil(s) and the tissues in the field of view of the coil(s). All models have their limitations, by assuming electrical and thermal properties and tissue dimensions, but they are generally considered conservative regarding safety. To overcome signal drop out at the location of the prostate due to destructive interference of the $B1^{+}$ field, multi transmit-receive surface array coils can be used in combination with a driving scheme to adjust the phase (and magnitude if necessary) of the transmitting elements within the array ($B1^{+}$ shimming. With this technique it is feasible to obtain 7 Tesla T2W TSE images with high SNR of the full prostate region with transmit-receive array coils only (9). To do so, the pulse durations of the excitation and refocusing pulses need to be prolonged and the flip angle of the refocusing pulses need to be brought back to 150°. Nevertheless, TSE imaging at 7 Tesla currently remains strongly limited by SAR, which prevents to take full advantage of the increased SNR.

Compared to the currently highest clinical standard (an endorectal coil at 3 Tesla), T2w MRI with an external transceiver coil array at 7 Tesla is not providing the same image quality yet, although many of the anatomical details are very well visible at 7 Tesla too (11). The contrast of peri-prostatic tissue appears different at 7 Tesla, because of low excitation and refocusing flip angles outside the $B1^{+}$ shimmed area with different chemical shift artifacts (different pulse lengths), diminishing contrast between muscles, lipids and bones. The combination with a receive only endorectal coil could further increase the resolution within the prostate (4). Full exploration and application of new MR techniques at 7T for the prostate are still in their infancy.

Initially, $^{1}$H-spectroscopic imaging has had considerable attention in the prostate at 7T. A transmit receive endorectal coil provided improved peak transmit and receive B1 but reduced B1 homogeneity compared to a transmit-receive external surface array. The rapid decrease of $B1^{+}$ with increasing distance from the coil limits the advantage of peak $B1^{+}$ performance and severely compromised anatomical imaging with conventional RF pulses (4,5). However, for $^{1}$H-MRSI this coil was very well suited because of the high B1+ close to the coil. To overcome the large $B1^{+}$ inhomogeneities and to reduce or prevent chemical shift displacements artifacts 3D $^{1}$H-MRSI sequences for 7 Tesla are semi or fully adiabatic (semi-LASER or LASER) (5,6). The chemical shift dispersion at 7 Tesla allows the design of chemical shift selective pulses that can effectively refocus spermine spins, which can be added to the semi-LASER sequence to obtain maximum signal from all metabolites of interest in the prostate (7). Next to field and TE related increase in SNR this can be a great advantage of 7 Tesla $^{1}$H-MRSI with respect to 1.5 or 3 Tesla $^{1}$H-MRSI (10). At 7 Tesla, the sensitivity of MR of nuclei other than protons may become high enough to be of clinical relevance. First results of phosphorus spectroscopic imaging of the prostate at a relevant spatial resolution in patients with prostate cancer within a clinically acceptable measurement time with a $^{31}$P endorectal loop coil have been performed. Extensive safety validations were performed to secure safe coil and sequence performance in an in vivo exam at 7 Tesla (8). The setup has now been used in explorative patient studies to characterize phosphorous signals in the prostate (12,13) and in prostate cancer (14) of which the results will be presented in this talk.

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