MRI of the Human Prostate in Vivo at 7T

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Introduction

Without contrast agent administration, T1 contrast in the prostate is very small (except for hemorrhage after biopsies). Therefore the clinical workhorse of prostate MRI is an axial multi-slice T2-weighted (T2w) acquisition of the prostate and surrounding tissues. When moving to ultra-high field strengths, multiple spin echo imaging becomes a challenge because of the increased radiofrequency (RF) power demand and increased RF power deposition inside the body, possibly exceeding safety limits. Spin echo MRI of the body at 7T requires dedicated measurement set-ups. With constructive addition of B_1 fields of multiple transmitter arrays flip angles of 180 degrees can be reached in deeper body regions such as the prostate. In order to calculate T2 values of the prostate and surrounding tissues at 7T to establish an estimate of the optimal echo time at this field strength for anatomical imaging, we implemented a multiple spin echo pulse sequence with prolonged RF pulses for use with a multi-transmit 8-channel array coil. In addition, we performed T1-weighted and mixed T1/T2-weighted MRI of the prostate and surrounding tissues to confirm the lack of contrast in T1-weighted images and to explore the possibilities of balanced gradient echo imaging of the prostate at 7T.

Methods

Four healthy volunteers (age 36, 33, 33 and 32 years, weight 82, 86, 74 and 70 kg) were examined on a 7T whole body MR system (Magnetom 7T, Siemens Healthcare, Erlangen). A home built 8-channel TxRx body coil array with meander elements was used [1] in conjunction with home built B_{1+} shimming and SAR supervision software [2]. After quick localizer images, RF shimming optimized the phases of 8 individual elements for maximal phase coherence within a region of interest (ROI) drawn around the prostate. In three volunteers the optimized phase settings were used in a single slice multiple spin echo sequence with prolonged 180˚ pulse durations (7.68 ms), an echo spacing of 15.0 ms, a total number of 8 echoes, and a repetition time of 2.5s (resolution 0.73 x 0.87 x 3.0 mm^3, scan time 7 minutes). The signal decay per pixel (excluding the first echo) was fit to a mono-exponential signal decay resulting in quantitative T2 images of the prostate and surrounding tissues. ROIs were drawn in these quantitative images over the complete peripheral zone, the transition zone and smooth muscles next to the prostate to estimate mean T2 values in these tissues. In one healthy volunteer a 3D TRUFI (True fast imaging with steady state free precession) and a 2D T1-weighted gradient echo (GRE) imaging sequence were run to explore mixed T2/T1 contrast and to confirm lack of T1 contrast inside the prostate. TRUFI parameters: TR 5.3 ms, TE 2.7 ms, flip angle in prostate ~40˚, resolution 0.86 x 0.86 x 1.3 mm^3, scan time 56 s. T1w GRE parameters: TR 500 ms, TE 12 ms, flip angle ~90˚, resolution 0.47 x 0.47 x 3.0 mm, scan time 2:46 min.

	Volunteer 1	Volunteer 2	Volunteer 3
Peripheral zone	62±11	64±13	65±9
Transition zone	48±12	50±14	53±8
Smooth muscle left	28±6	42±7	42±8
Smooth muscle right	29±6	42±7	36±6

Table 1*. Mean T2 values in msec. of an ROI of the entire peripheral zone and transition zone in one slice through the prostate of three volunteers. Muscle ROIs are comparable in size, chosen within the left and right smooth muscles.*

Results and discussion

In all volunteers the maximum required RF power for the prolonged 180˚ pulses in the multi echo sequence was between 40 and 60% of the maximum available RF power. The calculated T2 values for the peripheral zone and the transition zone of the three volunteers were very similar within the same tissue, but significantly different between the tissues (p<0.001, Table 1). T2 values of smooth muscles on different sides of the prostate were the same within volunteers, but differed between volunteers. Keeping the total amount of power deposited with the multi echo sequence (with full 180˚ pulses) within SAR safety limits restricted the acquisition of multiple slices: even though smaller flip angles (down to 120˚) or variable flip angles of refocusing pulses can decrease SAR considerably [3], a full set of T2w images with on the order of 20 slices covering the prostate is not within reach. Moreover, the difference in T2 values between peripheral and transition zone was significant but small, demanding a long echo time (and concurrent lower SNR) for a T2w image with high contrast, as used in a recent study with and without endorectal coils (TE 130 ms, [4]).

One alternative to limited-slice T2w MRI could be to emphasize the T2 contrast in a TRUFI sequence as much as possible. With an estimated flip angle of ~40˚ and a TR of only 5.3 ms some T2 contrast emerged in the 3D TRUFI sequence covering the whole prostate and surrounding tissues within one minute (Fig. 1). The anatomical detail in this sequence was superior to T2w imaging of the prostate of the same volunteer, and the absence of contrast within the prostate in the T1-weighted image series illustrates that any contrast in the TRUFI sequence was indeed originating from T2 weighting rather than T1 (Fig. 2).

Conclusion

Although measured in a small number of volunteers, T2 values of healthy prostate tissue of the peripheral zone and the transition zone have been established at 7 T. The small but significant difference in T2 demands the use of long echo times for T2w MRI of the prostate at 7T. As an alternative for anatomical imaging, 3D TRUFI MRI with short acquisition times can be explored.

References [1] Orzada ISMRM (2009) 2999; [2] Bitz ISMRM (2009) 4767; [3] Hennig et al Mag Res Med (2004) 51:pp.68-80; [4] Metzger et al Mag Res Med (2010) DOI 10.1002/mrm.22552

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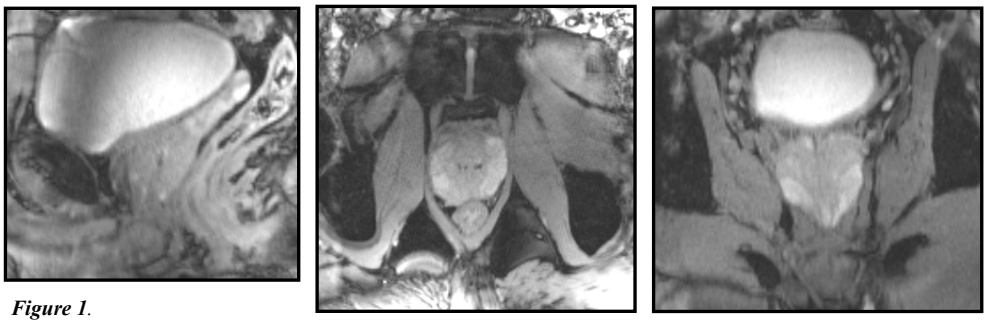

Figure 1*.*
Sagittal, axial and coronal view of a 3D TRUFI image set of the prostate and surrounding tissues of a healthy volunteer at 7T. In axial and coronal view, some contrast exists between the peripheral and transition zone.

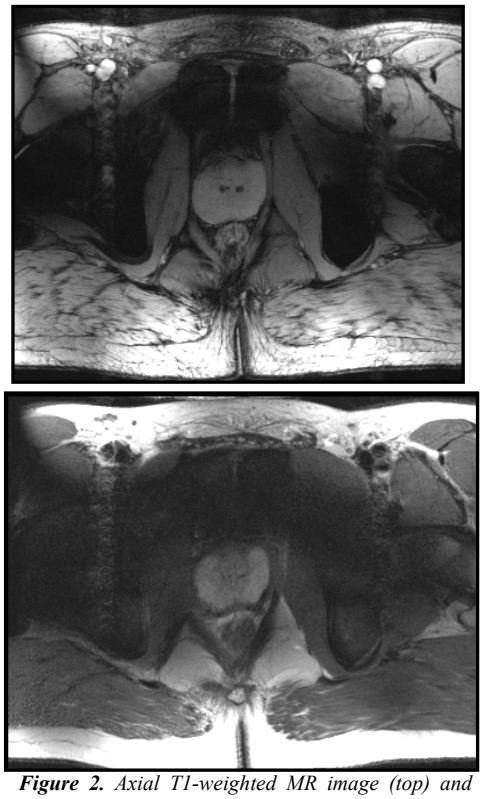

Figure 2. *Axial T1-weighted MR image (top) and T2-weighted fast spin echo image (bottom) of the lower abdomen of a healthy volunteer with the prostate in the center of the slice.*