Prostate MRI and MRSI with an endorectal coil at 3 T

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Abstract

The first results of high resolution T2-weighted imaging, spectroscopic imaging and (dynamic) contrast enhanced (DCE) imaging of the prostate at 3T with an endorectal coil are presented. The increased SNR at 3T was used to increase spatial, temporal and spectral resolution of these methods. In T2-weighted and post-contrast T1-weighted imaging the increased anatomical detail improved delineation of tumor tissue and evaluation of extracapsular extension. The high temporal resolution and SNR of DCE imaging increased the accuracy of pharmakokinetic parameters. In spectroscopic imaging the relevant individual resonances were well-resolved with minimal contamination from residual water and lipid signals.

Introduction

For appropriate management of prostate cancer (Pca) a clear delineation of the tumor is crucial, since extracapsular extension is an important parameter for staging the disease. Patients with organ-confined disease can be treated with radical retropubic prostatectomy or radiation therapy, whereas those with advanced disease can be treated with radiation therapy, hormonal therapy or a combination of both. Localized radiation therapy requires accurate localization and delineation of malignant tissue for precise delivery of radiation. The use of an endorectal surface coil to receive the MR signals at a magnetic field strength of 3T increases the MR signal to noise ratio (SNR) compared to all studies performed so far at 1.5T. This increase in SNR is used to increase the spatial, temporal and spectral resolution of T2-weighted imaging, spectroscopic imaging (SI) and (dynamic) CE imaging to improve localization and characterization of prostate cancer.

Materials and methods

This study was performed on a 3T MAGNETOM Trio whole body scanner (Siemens Medical Solutions, Erlangen, Germany) with an endorectal surface coil and external coil interface (Medrad Inc., Indianola, PA, USA). The scanning protocol consisted of three parts: First, high-resolution multislice T2 weighted turbo spin echo images were acquired in the axial direction for an anatomical overview of the prostate and surrounding tissues (5630/162 ms [TR/TE], 1024x512 matrix and 180mm FOV, scan time 6.5 minutes, 8 slices with thickness 4 mm). Second, a 3 dimensional CSI pulse sequence [1] with outer volume suppression was applied (700/168 ms [TR/TE], 65 x 56 x 70 mm FOV, PRESS localization 45 x 25 x 35 mm, elliptically sampled with 5 weighted averages, nominal pixel size 0.74 x 0.74 x 0.80 = 0.44 cc, scan time 12.5 minutes). Third, the passage of an intravenous bolus injection of a contrast agent (0.1 mmol/kg b.w. gadopentetate dimeglumine; Magnevist®; Schering, Berlin, Germany) was monitored dynamically with a T1-weighted 3D turboFLASH image series with a time resolution of 1 second (TR = 34 ms, TE = 1.61, $\alpha = 10°$, 128 x 64 (interpolated from 32 p.e. steps) x 10 matrix, 20% oversampling in slice direction, 140 x 70 mm FOV, 4 mm section thickness). Before contrast agent injection a reference measurement of the proton density was acquired (TR = 800 ms, $\alpha = 8°$, equal matrix size and FOV). The series of images was transferred to a separate workstation and analyzed with an in-house developed computer program to calculate bolus passage characteristics.

Results and discussion

The combination of an endorectal coil and a magnetic field strength of 3T for prostate MR imaging has allowed us to achieve an in-plane spatial resolution of 0.18 x 0.18 mm within an acceptable measurement time. In fig. 1 a large, low signal intensity lesion in the right peripheral zone and central gland is visible (arrows), corresponding with biopsy findings of PCa. The capsule in the right side of the prostate demonstrates bulging (open arrow).

The resonances of citrate and choline from the CSI measurements are important metabolic markers for the distinction between healthy or benign prostate tissue and tumor tissue [2,3]. In a representative spectrum of healthy peripheral zone in fig. 2 the spectral resolution and linewidths were sufficient to separate citrate, creatine and choline resonances from each other and from residual water and lipid resonances. At TE = 168 ms ($\tau 1$ = 10.6 ms) the strongly coupled citrate resonances appeared as two absorptive inner lines (merged together) and two dispersive outer lines. A different pulse timing, with shorter TE, will increase the SNR of the metabolites. Further studies including histopathology of removed prostates are necessary to determine which metabolite ratio is appropriate to reliably differentiate cancer from healthy prostate tissue with the pulse timing used at 3T.

The contrast agent uptake in the prostate could be monitored with an increased SNR and an increased temporal resolution of 1 second. A pixel-by pixel analysis of Gd-DTPA concentration-time curves was performed and resulting parametric maps were overlaid on the matching T2-weighted images. Figure 3 shows a markedly elevated maximum Gd-DTPA concentration in the suspected cancer region, which largely coincided with the hypointense areas in the T2 weighted image.

Conclusions

Endorectal MR imaging and spectroscopy at 3T offers great possibilities for accurate localization and staging of prostate cancer. The SNR benefit at higher field can be traded off for spatial resolution, temporal resolution and/or increased fit accuracy of contrast agent uptake analysis. This can result in improved staging of prostate cancer through better delineation of the prostate capsule and could guide localized radiation therapy. The increased spectral resolution at 3T enabled the detection of relevant metabolite resonances with minimal overlap from each other and from residual water and lipid signals, which can help improve the diagnostic accuracy for prostate cancer.

References: 1. Scheenen et al, abstract #791, ISMRM 2002; 2. Kurhanewicz et al, *Urology* 45: 459-466, 1995; 3. Heerschap et al, *Anticancer Res.* 17: 1455-1460, 1997

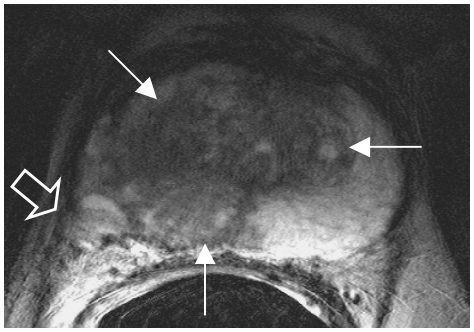

Figure 1. An axial T2-weighted TSE image at 3T of prostate carcinoma in a 64-year-old man.

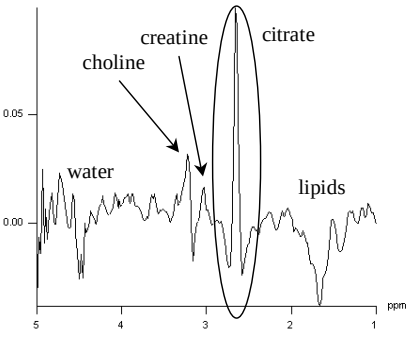

Figure 2. One spectrum from healthy prostate tissue from a 3D MRSI dataset.

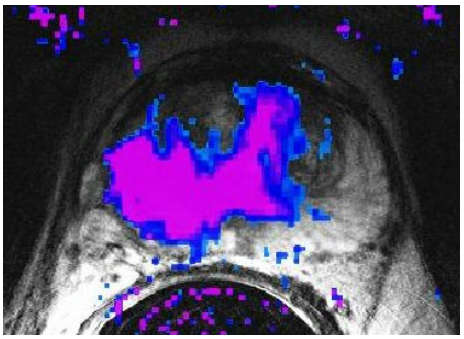

Figure 3. The elevated, fitted maximum [Gd-DTPA] in a region with prostate cancer.

Note: after uploading of this abstract, resolution loss occurred in all figures