3D 1H-MR Spectroscopic Imaging of the in vivo Human Prostate at 3T with a body array coil: a step towards MR screening of prostate cancer?

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Introduction

Proton MR spectroscopic imaging (MRSI) of the human prostate has proven to be a valuable addition to conventional MR imaging in the detection and localization of prostate cancer (1). Signals of citrate, creatine and choline can be detected throughout the prostate, with increased levels of choline and decreased levels of citrate characterizing cancer tissue (2-3). A major topic of debate in prostate spectroscopy is the use of an endorectal coil (ERC), either rigid or inflatable. Apart from substantial discomfort from this coil for the patient, insertion and evaluation of coil position takes valuable MR scanner time in clinical practice. Here we introduce the concept of three-dimensional (3D) MRSI with a body array coil at 3T in patients with prostate cancer with whole-mount section histopathology as the standard of reference.

Materials and methods

Twenty-two consecutive, biopsy-proven prostate cancer patients were referred to our Radiology department for disease staging. After written informed consent for an additional MRSI we used an eight-element body array coil of the 3T MAGNETOM Trio system (Siemens Medical Solutions, Erlangen, Germany) for T2-weighted imaging and MRSI (total MR time ~20 minutes). The MRSI pulse sequence was an acquisition weighted PRESS sequence with optimized 180 degree pulses, two dual-band frequency selective excitation pulses to suppress water and lipids, and up to eight outer volume saturation slabs (adapted from (4)). After filtering (100% Hanning filter), zerofilling to the nearest power of two and Fourier transformation of the three spatial directions the signals of the eight coil elements were combined into one spectrum for every voxel (5). Parameters and timing (6) for the 3D MRSI measurement were: TE 145 ms; TR 750 ms; FOV, matrix size and averages adapted to prostate size, nominal voxel volume of 7 x 7 x 7 mm and total acquisition time between 8 and 9 minutes. After radical prostatectomy the prostate specimens were routinely prepared and stained with hematoxylin and eosin. A single experienced pathologist who was blinded to the MR results outlined the presence and extent of cancer. Blinded to the spectra, a radiologist together with a MR spectroscopist matched the histopathological results to corresponding MRSI voxels overlaid on T2-weighted images.

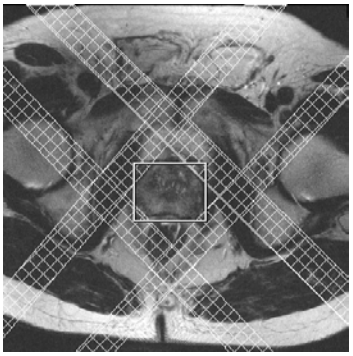

Figure 1. An axial T2-weighted image of a patient with prostate cancer with the PRESS box and outer volume saturation slabs of the MRSI pulse sequence around the prostate.

Results

In the axial T2-weighted images of the patients the prostate was clearly visible inside the PRESS-excited volume (Fig.1). Signals of citrate, creatine and choline were measured throughout the whole prostate, without severe baseline distortions or lipid contamination (example in Fig.2, bottom line). The true resolution of the MRSI voxels (incorporating filtering) can best be approximated by a sphere with a diameter of 1.78 (broadening by filter) x 7 = 12.5 mm. This corresponds to a volume of 1.0 cm^3. The true voxel size is indicated with a blue circle in the spectral maps in Fig. 2.

Generally, spectra from voxels from locations within the tumor showed increased levels of choline and decreased levels of citrate. The spectral resolution at 3T made it possible to fit the choline resonance separately from the creatine resonance, enabling the calculation of the choline to citrate ratio (Cho/Ci ratio). This ratio is presented in Figure 3 for arbitrarily chosen voxels in the healthy peripheral zone, central gland and (peri-)urethral zone of all patients, together with ratio values from voxels in tumor foci. Four values of the ratio that were larger than 1 were set to 1 in this graph. Although overlap exists, it is clear that spectra from tumor voxels generally have an increased Cho/Ci ratio. Differences also exist between healthy tissues, as the mean value of the Cho/Ci ratio in the peripheral zone (0.14 ± 0.05 SD) is lower than in the central gland (0.20 ± 0.08 SD) and peri-urethral zone (0.20 ± 0.09 SD).

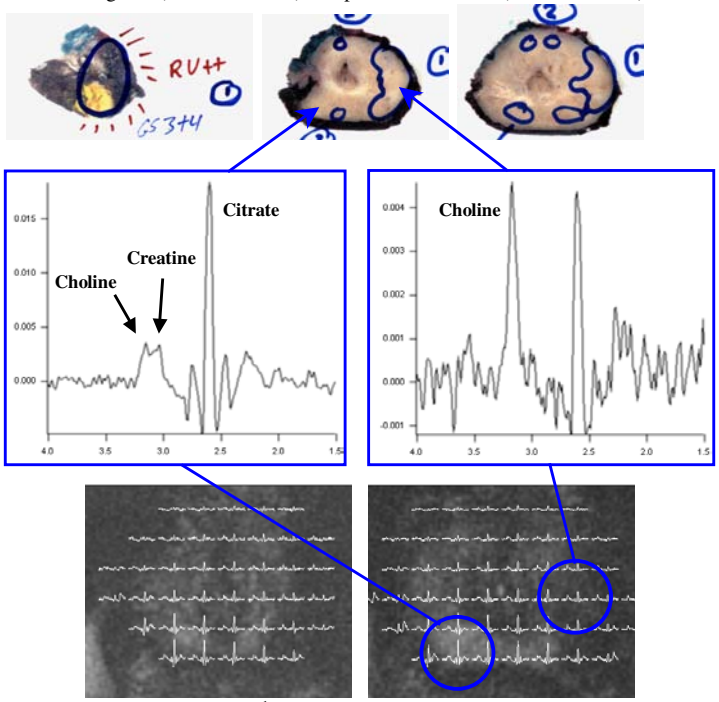

Figure 2. Histopathology and 3D ^{1}H-MRSI examination of the apex of the prostate of a patient with prostate cancer. The top row of images shows the histopathology of this patient with tumor foci outlined in blue. At the bottom two complete spectral maps (range from 2.0 to 3.5 ppm) through the apex are overlaid on T2-weighted images. From two locations the spectra are shown in detail: healthy peripheral zone with high citrate and intermediate choline + creatine signals on the left and tumor tissue with decreased citrate and increased choline on the right.

Discussion and conclusions

3D MRSI of the prostate *in vivo* with a voxel resolution of 1 cm^3 can be done at 3T with a body array coil in 8.5 minutes. The Cho/Ci ratio of tumor tissue enables the discrimination between tumor and healthy tissue, and therefore enables the detection of prostate cancer without the use of an endorectal coil. The size of the smallest detectable tumor with the used spatial resolution is difficult to predict as exact matching of histopathology with in vivo MR imaging is a challenge.

Not using an endorectal coil simplifies the clinical examination and reduces patient discomfort and total examination time. As a completely non-invasive combination of MR methods T2 weighted imaging and MRSI can therefore be an important step to more widespread use of MRSI in the detection, localization and evaluation of prostate cancer.

References:

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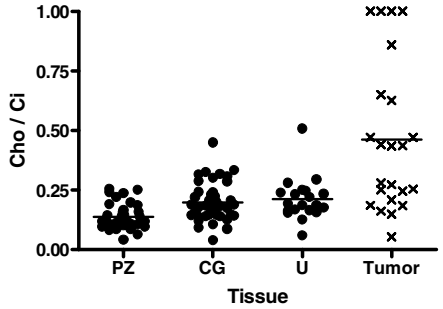

Figure 3. Choline to citrate ratio of healthy and tumor tissue of 22 patients. PZ peripheral zone, CG central gland, U (peri-)urethral zone.