3D 1H-MR Spectroscopic Imaging of the in vivo Human Prostate with Combined External Coils

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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). With *in vivo* 3D ^{1}H-MRSI signals of citrate, creatine and choline can be detected throughout the prostate. Cancer tissue is characterized by increased levels of choline and decreased levels of citrate (2-3). A major issue in prostate spectroscopy is the use of an endorectal coil (ERC), either rigid or inflatable. Apart from the substantial patients discomfort from this coil, the introduction of a large volume of air (when an inflatable ERC is used) close to the prostate will make it more difficult to homogenize the magnetic field in the prostate itself. The use of one external coil for prostate spectroscopy at 1.5T has been suggested and evaluated before (4-5), but to our knowledge no combination of multiple external coils for 3D MRSI of the prostate is reported. We present a simple and elegant method to combine the signals from multiple external coils for 3D MRSI of the prostate with a spatial resolution of 1.7 cm^3 within 11 minutes. If the sensitivity for prostate cancer can be obtained with MR imaging (e.g. dynamic contrast enhanced MRI) the specificity of MRSI for cancer tissue could be provided by the method presented here.

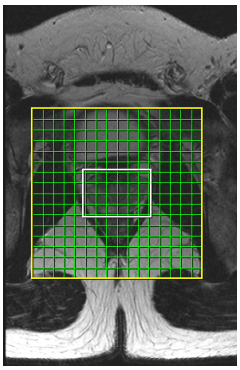

Figure 1. Position of the interpolated MRSI matrix on an axial T2-weighted image.

Materials and methods

The standard imaging setup of 6 spine array coil elements in the table and two body array coil elements on top of the subject was used for MRI and MRS of the prostate of a 25-year-old healthy volunteer of average physique (1.82 m, 82 kg). We used an acquisition weighted PRESS pulse 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 (6) on a 1.5T MAGNETOM Sonata whole body scanner (Siemens Medical Solutions, Erlangen, Germany). After filtering (100% Hanning filter), zerofilling to the nearest power of two and fourier transformation of the three spatial directions the signals of the four used coil elements were combined as follows: from every individual voxel the phase of the first point of the echo (zero order phase) of the different coil elements was calculated and used to set the complete signal in-phase. By definition the first order phase of the four signals – defined by the exact moment in time of sampling the data point at the echo top – is equal, since the signals from the different coils is sampled at exactly the same time by four separate receiving channels. Then for every individual voxel the phased signals were averaged, weighted by the amplitude of the data point at the echo top of the signal of every contributing coil. After combining the signals, the spectral dimension was fourier transformed into spectra that only needed a first order phase correction. Parameters for the 3D MRSI measurement: FOV 100 x 100 x 100 mm, matrix 12 x 12 x 12, TE 120 ms, TR 640 ms, 6 weighted averages, total acquisition time 10 min 45 s, acquisition bandwidth 1250 Hz, 512 spectral data points. As an anatomical overview of the prostate and surrounding tissues high-resolution multislice T2 weighted turbo spin echo images in three directions were acquired first (3500/132 ms [TR/TE], 512x256 matrix and 280x140mm FOV, scan time 2 min 48 s, 15 slices with thickness 5 mm).

Results and discussion

As can be seen in Fig.1, the field of view of the MRSI matrix is much larger than the prostate itself (visible in the white box which is selected by the three PRESS pulses). The PRESS volume selection, together with this large FOV, the weighted k-space acquisition and filtering, the combined lipid and water suppression and the outer volume saturation slabs around the prostate all contributed to the succesful measurement of citrate, creatine and choline throughout the whole prostate (Fig.2). For all voxels in Fig.2 only a first order phase correction was necessary to produce an in-phase spectrum. The automated combination of the regularly used coil elements took care for zero order phasing. The true resolution of the voxels (incorporating filtering) can best be approximated by a sphere with a diameter of 1.78 (braodening by filter) x 100 mm (FOV) / 12 (p.e.steps) = 15 mm. This corresponds to a volume of 1.7 cm^3. Filtering the acquisition weighted spatial dimensions increases the signal to noise (SNR) per unit time, it braodens the spatial response function of a voxel (factor 1.78 (7)), and it strongly reduces contamination from one voxel to the other. This feature is very helpful in reducing lipid contamination from outside the prostate, and also in correctly localizing metabolite signals inside the prostate. The shown resolution in Fig. 2 (squared voxels of 100 / 16 = 6.25 mm) is much smaller than the true resolution of the measurement (more sphere-shaped voxels with radius 7.5 mm), which removes the need for regridding the matrix to acquire a spectrum of a certain anatomical position. If the true resolution, that can still be increased at the expense of measurement time, is enough to provide specificity for prostate cancer, and the sensitivity for cancer tissue can be acquired with a different method (e.g. dynamic contrast enhanced MRI) the use of the ERC could be omitted. If the ERC ís used, it can be combined with other (external) coil elements for a possible increase in SNR in more ventral parts of the prostate that are not well covered by the reception profile of the ERC. Not using an ERC could improve the local shim of the prostate, especially at a field strength of 3T, for which the possibilities of combining coils in 3D MRSI of the prostate are now easy accessible, but yet to be explored.

Conclusions

3D MRSI of the prostate *in vivo* with a useful resolution can be done at 1.5T without an endorectal coil by using an automated weighted combination of spectroscopic signals from multiple external receiver coils (or standard coil elements).

References:

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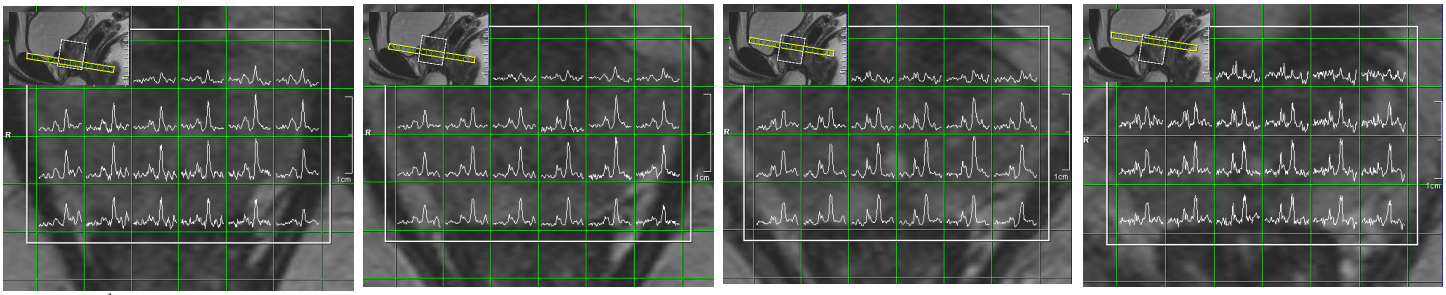

Figure 2. 3D ^{1}H-MRSI examination of the prostate of a healthy volunteer. All voxels in the four slices through the prostate show relevant metabolite signals. In the small insets the relative positions of the MRSI slices on a sagittal T2-weighted background image are shown. In every voxel the spectrum from 1.8 to 4.0 ppm is shown after manual first order phase correction.