Fast 3D proton MR spectroscopic imaging of the human prostate *in vivo* at 3 Tesla using "spectroscopic Missing Pulse – SSFP"

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Introduction

Proton MR spectroscopic imaging (^{1}H MRSI) of the human prostate is a promising tool to increase the specificity in differentiating prostate cancer from healthy tissue [1]. Prostate cancer is characterized by increased levels of choline and decreased levels of citrate [2,3] which both can be detected *in vivo* throughout the whole prostate with 3D ^{1}H MRSI. Since the splitting of the creatine (3.0 ppm) and choline (3.2 ppm) resonances is hampered *in vivo* by the underlying signals of polyamines, the use of fast spectroscopic SSFP sequences [4] with their limited spectral resolution could be promising to further reduce the total measurement time of 3D ^{1}H MRSI examinations at 3 Tesla [5] while maintaining a high SNR_t. Such examinations of the prostate inevitably demand an excellent lipid suppression to avoid signal contamination of voxels inside the prostate by periprostatic lipid resonances. Therefore, we evaluated the feasibility of 3D ^{1}H MRSI of the prostate *in vivo* using the "spectroscopic Missing Pulse - SSFP" (spMP-SSFP) sequence [6] with which 2D spatial preselection is possible. Furthermore, four outer volume suppression (OVS) slabs are included to additionally suppress lipid signals in the third spatial dimension. Measurements were conducted on phantoms, healthy volunteers and patients with prostate cancer.

Materials and methods

In order to test the performance of the spMP-SSFP sequence for 3D ^{1}H MRSI *in vivo*, the routine MR protocol including a PRESS MRSI measurement [5] of two patients with biopsy-proven prostate cancer was extended with an additional MRSI examination with the spMP-SSFP sequence. We used an endorectal coil on a 3T MAGNETOM Trio system (Siemens Medical Solutions, Erlangen, Germany) for T2-weighted reference imaging and both MRSI measurements (total measurement time ~30 minutes). In the spMP-SSFP pulse sequence RF excitation is performed with spectral-spatial composite pulses which are simultaneously slice and chemical shift selective suppressing both water and lipid signals. The second composite pulse excites an orthogonal slice with respect to the slice of the first composite pulse enabling 2D spatial preselection (in y and z direction). Fig.1 shows the field-of-view (FOV) and the excited volume-of-interest (VOI) with FOV(x,y,z): 168x72x72mm³ and VOI(x,y,z): 168x30x35mm³ (second patient: 168x28x34mm³). The FOV in the non-selective third spatial dimension (x) is larger than the FOV in the spatial selective directions to avoid wraparound of signals into the prostate. Additionally, four OVS slabs are used to reduce lipid signals primarily in the non-selective direction. The number of phase encoding steps in this direction is increased to achieve a better localization of residual lipid signals (phase encoding steps(x,y,z): 28x12x12) minimizing lipid signal contamination of voxels inside the prostate. Further measurement parameters were: TE=130ms, TR=195ms (second patient: TR=202ms), α_1=44°, α_2=-44° (second patient: α_1=50°, α_2=-50°), acquisition bandwidth=1200Hz, 128 spectral data points, acquisition weighted k-space sampling with 6 averages, total measurement time: 8min34s (second patient: 8min52s). The acquisition weighted sampling scheme broadens the voxel by a factor of 1.78. Data were apodized in the spectral dimension with a Gaussian function, zerofilled to 1024 spectral data points, Fourier transformed and displayed in magnitude mode due to the acquisition of full spin echoes with spMP-SSFP. Parameters for the optimized PRESS MRSI sequence were: FOV(x,y,z): 84x60x60mm³, VOI(x,y,z): 52x30x35mm³ (second patient: 54x28x34mm³), phase encoding steps(x,y,z): 14x10x10, TE=145ms, TR=750ms, acquisition bandwidth=1250Hz, 512 spectral data points, acquisition weighting with 5 averages, total measurement time: 8min37s. The voxel is broadened by a factor of 1.78 due to the acquisition weighted sampling scheme. Postprocessing consisted of spectral apodization with a Gaussian function, zerofilling to 1024 spectral data points, FFT and phase correction.

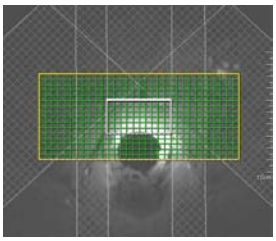


Fig.1: FOV (yellow line) and VOI (white line). In the non-selective direction the FOV is larger and the VOI is only displayed to localize the prostate.

Results

Fig.2 displays spectra of patient 1 from the same region recorded with the PRESS (Fig.2a,c) and the spMP-SSFP (Fig.2b,d) sequence. In Fig.2a and 2b spectra of healthy prostate tissue are shown with signals of citrate (2.6 ppm), creatine (3.0 ppm) and choline (3.2 ppm), while the signal of citrate is decreased compared to choline in Fig.2c and 2d for both PRESS and spMP-SSFP. This increase of the choline + creatine / citrate ratio is indicative of cancer tissue. In the spMP-SSFP spectra an additional signal around 3.55 ppm is present almost throughout the prostate. Spectral matrices in Fig.3 provide an overview of metabolite distributions from one slice of the prostate of patient 2. Citrate signals are decreased in the right peripheral zone and central gland in both measurements. In Fig.3b residual lipid signals are visible in some voxels of the spMP-SSFP measurement close to or inside periprostatic fat.

Discussion and conclusion

The results prove that 3D ^{1}H MRSI of the human prostate *in vivo* using spMP-SSFP is feasible. The lipid signals originating from periprostatic fat tissue are suppressed to metabolite signal levels inside the prostate with the aid of 2D spatial preselection and additional OVS slabs. In the currently used implementation the reduced TR compared to the optimized PRESS based MRSI sequence does not shorten the total measurement time because of the large FOV and the large number of phase encoding steps needed to prevent aliasing artifacts in the non-selective spatial dimension and to localize residual lipid signals better. The additional signal around 3.55 ppm in the spMP-SSFP measurements probably originates from a singlet signal due to the small linewidth. It may be possibly assigned to glycine but this has to be analyzed further. This signal is suppressed in the PRESS sequence by the dual-frequency suppression of water and lipids. A fair comparison of spMP-SSFP and the optimized PRESS sequence in terms of SNR_t is yet to be explored as well as optimal sequence parameters of the spMP-SSFP sequence regarding the strongly coupled resonances of citrate.

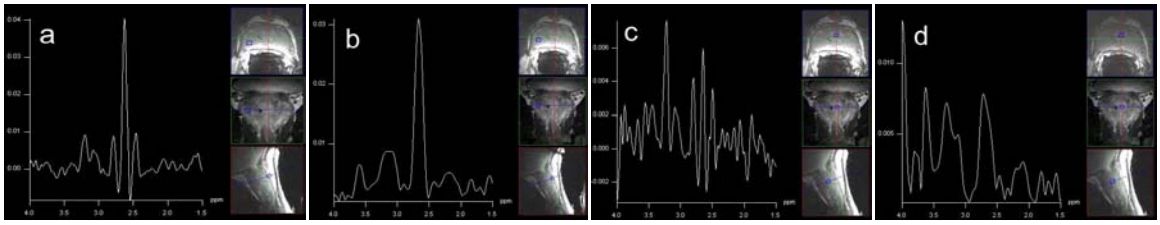
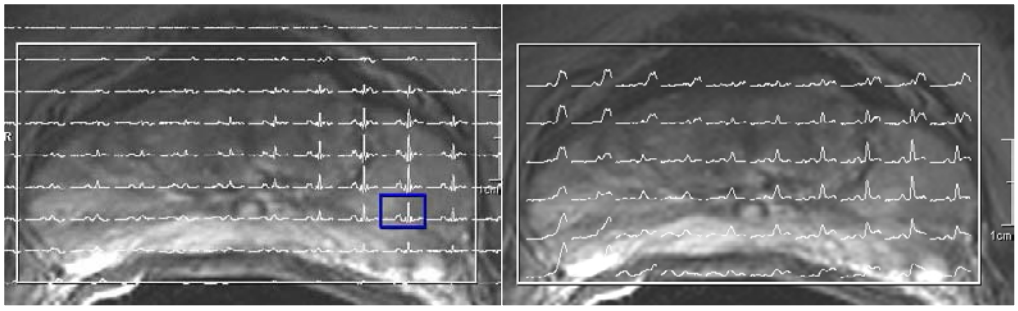


Fig.2: single spectra of patient 1

Fig.3: one slice of the 3D ^{1}H MRSI measurement of patient 2
a) PRESS *b) spMP-SSFP*



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