Proton relaxation times of human prostate metabolites at 3 T

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Target audience

Physicists involved in MR spectroscopy of the prostate.

Purpose

To measure T_1 and T_2 relaxation times of water, choline (Cho), creatine (Cr), and citrate (Cit) of healthy human prostate at 3 T.

Methods

Nine healthy volunteers were measured (median age 57 years, range 27-67). Prostate specific antigen level of volunteers was between 0.4 and 2.7 ng/mL. Volunteers were scanned on a 3 Tesla clinical system (Philips, Achieva) using a circular two-element receiver coil (diameter 20 cm) placed in the front and back of the pelvis. Single-voxel spectra were acquired using PRESS sequence (spectral bandwidth 2000 Hz, 1024 points, delay time between 90^o and the first 180^o pulse, 18.3 ms). Voxel, as large as possible, was placed inside the prostate. Iterative first-order shimming was used for magnetic field homogeneity correction. Band-selective pre-pulses and BASING pulse were used for water suppression. Fat suppression was achieved by a frequency-selective inversion recovery pre-pulse. Spectra acquired with nine TRs (0.7, 0.85, 1, 1.4, 1.8, 2.2, 3, 4, 5 sec, TE 140 ms, number of scans (NS) 16), and seven TEs (125, 150, 175, 200, 225, 250, 275 ms, TR 1500 ms, NS 16) were used to obtain relaxation times of the water. T_2 values of the Cho and Cr were estimated using the spectra measured at five TEs (120, 140, 175, 240 or 250, 260 ms, TR 1500 ms, NS 192) (Fig. 1). T_2 values of Cit were computed from the two spectra measured at TE 140 and 260 ms (TR 1500, NS 256).[1] T_1 values of Cho, Cr and Cit were estimated from the spectra measured at TE 140 ms and TRs 0.825, 0.9, 1, 1.25, 1.5, and 2 or 4 sec (NS 192) (Fig. 1). BASING pulse was used for fat suppression instead of inversion recovery pre-pulse, which enabled a decrease in the minimum TR, to 825 ms. The spectral intensities used for relaxation time estimations of water, Cho, and Cr were determined by fitting of the Gaussians using a nonlinear least-squares algorithm AMARES (MRUI) (Fig. 2). Spectral intensities of Cit at echo times 140 and 260 ms were fitted by LCModel. Relaxation times T_1, T_2 were determined by mono-exponential fitting of the spectral intensities using a software package ORIGIN (OriginLab, Northampton, MA). Spectral intensities vs. TE or TR times were fitted by functions $y = A*\exp(-x/T_2)$, and $y = B - B*\exp(-x/T_1)$, A, B = const, respectively. Citrate T_2 values were estimated using equation $\ln(y) = \ln(A) - x/T_2$.

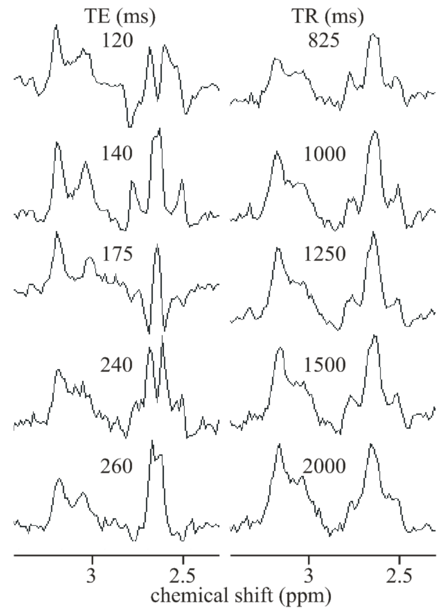

Fig.1: Prostate spectra acquired at increasing TE (TR = 1.5 s) and TR (TE = 140 ms).

Results

Relaxation times are reported for prostate water (T_1, 2163±166 ms; T_2, 110±18 ms), Cho (T_1, 987±71 ms; T_2, 239±24 ms), Cr (T_1, 1128±149 ms; T_2, 188±20 ms), and Cit (T_1, 476±70 ms; T_2, 228±42 ms). Spectral intensities of five volunteers were fitted to estimate relaxation times of the water. Spectra of five volunteers were used for T_1 estimation of Cho, Cr, and Cit. Spectral intensities of six volunteers were used to compute T_2 values of Cit. One or two outliners were typically excluded from the fitting. The most difficult step was estimation T_2 relaxation time of Cho and Cr. Reliable determination of Cho and Cr intensities was successful only in the spectra with SNR $\geq$ 4 for Cho. This SNR was achieved in the spectra of three older volunteers (60, 62, 67 years) due to an increased voxel size (21-28 cm^3).

Discussion

To our knowledge, this is the first 3 T study in which Cho, Cr, and Cit relaxation times of healthy human prostate were estimated. For the first time were 3 T relaxation times measured by single-voxel MRS and for the first time were estimated Cr T1, T2 values. Our water T_1 is higher than the value 1597 ± 42 ms estimated by MRI,[2] however, T_2 value lies between the published values of 74 ± 9 ms, for the whole prostate, and 142 ± 24 ms, for peripheral zone.[2,3] The relaxation times estimations of Cho, and Cit can only be compared with 2D MRSI measurements of a mixture of normal and malignant prostate tissue (Cho T_1 1100 ± 400 ms, T_2 220 ± 90 ms; Cit T_1 470 ± 140 ms, and T_2 170 ± 50 ms). [4] These relaxation times are in line with our values taken into account standard deviations.

Conclusion

We have shown that single-voxel spectroscopy using a surface coil is an effective method for estimation of prostate Cho, Cr, and Cit relaxation times. Knowledge of the relaxation times enables quantification of prostate metabolite concentrations using water as the internal concentration reference.

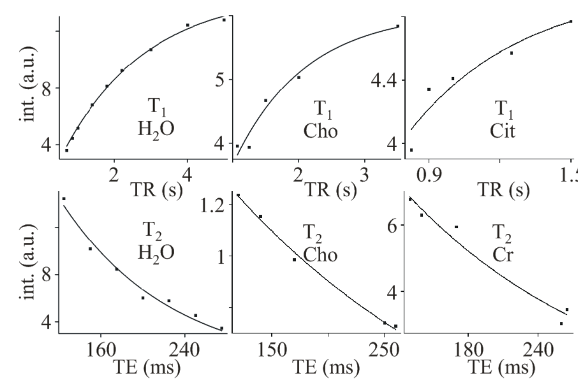

Fig.2: Representative examples of the mono-exponential fits of spectral intensities vs. TR and TE.

References

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