Spectroscopy of the human prostate at 3 Tesla using surface coil: Age-related changes

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Introduction

[1]H-MR spectroscopy of the prostate at 1.5 T is only possible using an endorectal (ER) receiver coil to achieve acceptable spatial resolution and signal-to-noise ratio (SNR). Although ER coils are available for 3 T scanners as well [1, 2] they are rarely used because of high cost. ER coil is contraindicated in a number of patients especially after the surgery and radiotherapy. The patient's discomfort from the coil hinders clinical settings, such as in a screening population, radiation therapy planning or in a recruitment of healthy volunteers. The problem could be solved by MR scanners operating at 3 Tesla and above. These scanners enable prostate spectroscopy without the use of an ER coil [3, 4]. The goal of the present study is threefold: (i) to measure high quality prostate spectra at 3 T using surface coil that can be used for development a new LCModel algorithm [5], (ii) to evaluate LCModel spectrum processing, (iii) to study the age-dependent effects using spectra of large number of healthy volunteers.

Materials and Methods

The study included 53 healthy volunteers ranging in age from 26 to 72 years. Medical histories were obtained to exclude any pathologic urologic condition, specifically prostatic disease and voiding problems. Single-voxel (SV) spectroscopy and 2D MR spectroscopic imaging (MRSI) were performed in each volunteer. The measurements were performed on a Philips Achieva 3T scanner. The spectra were acquired with a circular two-element receiver surface coil (loop size 20 cm). The SV spectra were measured using PRESS sequence (TR/TE 1500/140 ms, BW 2000 Hz, 1024 points, 16 phase cycle steps). 16 non-water-suppressed scans were followed by 192 water-suppressed. Mean voxel size was 13.0 ± 5.8 cm^3 (range 7.7 – 49 cm^3). Water suppression was achieved using band-selective excitation pre-pulses followed by BASING pulse [6]. Fat suppression was accomplished by a frequency-selective inversion recovery pre-pulse. Total scan duration was 5 min. 15 sec. SV MRS was followed by 2D MRSI (PRESS, TR/TE 1400/140 ms, spectral BW 2000 Hz, 1024 points, SI resolution 16x16, FOV = 160 mm, slice thickness 20 mm, 3 acquisitions, circular encoding with reduction factor of 25%). Fat suppression was accomplished by a frequency-selective inversion recovery pre-pulse. A dual BASING-type pulse was used for water and residual fat suppression. A rapid 2D MRSI of the water signal (matrix 8x8, 1 acquisition) was performed prior to the actual measurement. This acquisition was used in the data processing to correct eddy-current distortion, and to assist in phasing of the spectra. Net measurement time was 15 min. 15 sec. We used relatively large nominal voxel size (10x10x20 mm^3) to be able to cover most part of the prostate within one 2D MRSI measurement and to ensure acceptable SNR.

Quantification of metabolite-to-citrate peak area ratio was accomplished by customized LCModel (v. 6.2-1G). The algorithm fits spectra using a simulated basis sets. SNR < 3 (vendor's recommendation) was used as a criterion to reject spectra instead of Cramer-Rao Lower Band (CRLB). CRLBs were significantly underestimated as they are with all empirical peak-fitting models. Following spectral lines were fitted: total choline (Cho), creatine (Cr), polyamines (PA) and citrate (Cit). Baseline and phase corrected spectra were normalized by summing the squares of the intensities of each spectral point and then dividing the amplitude of each point by the square root of this sum [7]. Mean spectra were computed by averaging the values at each data point (Fig. 3).

Results

Figure 1 shows representative SV spectrum of a healthy volunteer and LCModel fits. Normalized 2D MRSI spectra of the same volunteer are shown in Fig. 2. Figure 3a show mean SV spectrum of n = 13 youngest volunteers (mean age 35.4 ± 4.9 years, range 26-40). Spectrum of the oldest group (64.3 ± 4.4 years, range 59-72, n = 10) is shown in Fig. 3b. Figure 4 demonstrates changes in SV spectral intensity ratio (Cho+PA +Cr)/Cit with increasing age. Comparisons of spectral intensity ratios of 23 younger (mean age 38.3 ± 5.1 years, range 26-44) and 20 older volunteers (age 58.9 ± 6.2, range 51-72) are shown in Fig. 5.

Discussion

The spectral resolution appears excellent and the SNR is high enough to carry out in vivo human studies (Fig. 1, 2). LCModel spectrum processing results are encouraging. LCModel's regularization procedure is capable to fit overlapped resonances of Cho, PA and Cr between 2.9 and 3.3 ppm as well as all four peaks (doublet of doublets) of the citrate. Automated processing reduces user interaction and individual bias to a minimum. To our knowledge, this is the first study that uses LCModel optimized for the prostate
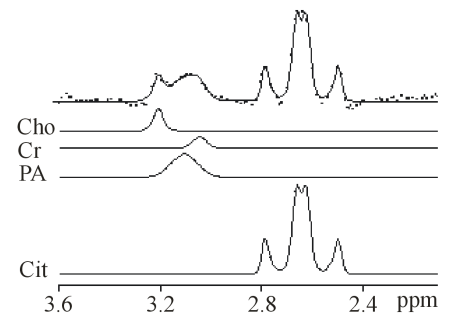

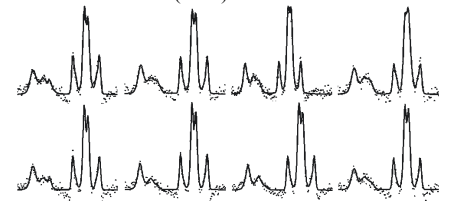**Fig. 1:** SV spectrum of the normal prostate (dots) and LCModel fits (lines). SNR = 12.

Fig. 2: Normalized 2D MRSI spectra (dots) of the same volunteer (Fig. 1) and LCModel fits (lines). $8 \le SNR \le 10$.
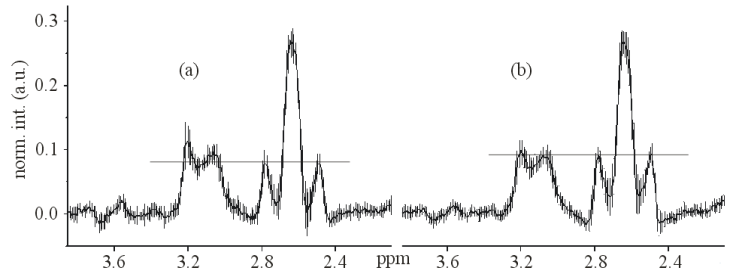

Fig. 3: Normalized mean SV spectra of healthy prostate and standard deviations. (a) Age group 26-40 years, n = 13, (b) age group 59-72 years, n = 10.
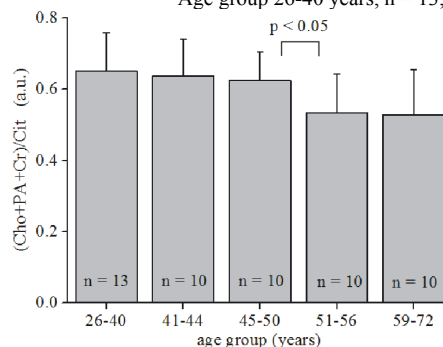

Fig. 4: Mean (Cho+PA+Cr)/Cit spectral intensity ratio for different age groups.
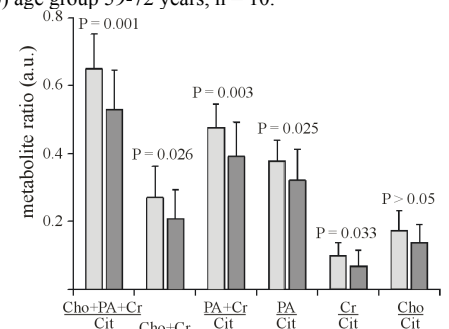

Fig. 5: Mean spectral intensity ratio for younger (age < 45 years, light gray) and older (age > 51 years, dark gray) volunteers.

spectra acquired at 3 T. Figure 3, 4, and 5 demonstrate main spectral intensity changes with increasing age. Significant decrease was found in (Cho+PA+Cr)/Cit spectral intensity ratio between age groups 45-50 and 51-56 years (Fig. 4). Metabolite-to-Cit spectral intensity ratios are significantly lower in older individuals than in younger volunteers (Fig. 5), primarily owning to an increase in Cit levels in benign prostatic hyperplasia of the central gland [8].

Conclusion

Our results demonstrate that the prostate spectroscopy at 3 T is feasible using surface coil. LCModel provides a high level of accuracy for analysis of prostate spectra. Our results indicate that each ^{1}H MRS study of the human prostate should include age-matched controls.

References

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