Absolute Quantification in 1H MRSI of the Prostate at 3T

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Introduction

Magnetic Resonance Spectroscopic Imaging (MRSI) detects abnormal metabolism rather than abnormal anatomy and has shown considerable promise in the local evaluation of prostate cancer (PCa). It is common to use the (Choline + Creatine)/Citrate ratio when assessing the pathological state of the prostate. However, the use of citrate (Cit) as a reference for detecting the increase in choline (tCho) levels is questionable in the context of prostatitis or treatment such as hormonotherapy and radiotherapy: the reduced citrate rendering this approach inappropriate. We propose an absolute quantification method for MRSI at 3T whereby both choline and citrate are expressed in millimoles/kg.

Materials and Methods

Thirty-six patients (16 with negative biopsies / 20 with sextant TRUS-guided biopsy proven prostate cancer) underwent MRI/MRSI of the prostate on a 3T whole body magnet (Siemens Magnetom Trio TIM) using a pelvic multi-channel phased-array coil only. Three-dimensional axial T2-weighted fast spin-echo (TR/TE/ETL: 3000 msec./143 msec./109, slice thickness: 1.25 mm) images were acquired. Nominal matrix and FOV were 320 x 256 and 280 x 240 mm^2. Three-dimensional MR spectroscopic imaging data were acquired using a water and lipid-suppressed double-spin-echo point-resolved spectroscopic (PRESS) sequence. Data sets were acquired as 16 x 12 x 8 (interpolated to 16 x 16 x 8) phase-encoded spectral arrays giving nominal spectral resolution of 0.28 cm^3 (0.21 cm^3 after interpolation), TR/TE: 720/140 ms. All patients received four additional unsuppressed water acquisitions performed using a reduced acquisition matrix extrapolated to match the other data sets (i) at the same TR, but with TE of 30, 80 and 140 ms and (ii) at TR/TE of 2000/30 ms in order to evaluate T2 and T1 of tissue water. In 19 patients, additional water-suppressed spectra were acquired using a set of different TR (510, 1200 and 2000 ms) in order to evaluate T1-dependance of tCho and Cit. Given the complex coupling behaviour of Cit, T2-dependance was not investigated and literature values were taken. Spectra were analysed using LCModel for tCho, Polyamine (PA), Total Creatine (tCr) and Cit. Absolute concentrations for tCho and Cit as follows;

$$[\text{Metabolite}] = \{ 2\, S_m * [\text{Water}] * e^{(TE/T2w)} * (1-e^{(-TR/T1w)}) \} / \{ n_m * S_w * e^{(TE/T2w)} * (1-e^{(-TR/T1m)}) \}$$

where S_m and S_w are peak integrals for metabolites and water, n_m is the number of protons associated with peak, $T1_m$, $T2_m$, $T1_w$ and $T2_w$ are the relaxation times of metabolites and water. Tissue water concentration [Water] was approximated to 39.4 moles/kg (3). Absolute concentrations of tCho and Cit in peripheral zone (PZ) and central gland (CG) tissue were estimated in all patients and sorted according to (i) PZ tissue with negative biopsies and absence of low intensity signal on T2-weighted images, (ii) normal appearing CG tissue, (iii) Benign Prostatic Hyperplasia (BPH) within CG and (iv) confirmed prostate cancer from low intensity signals on T2-weighted images and positive biopsies in that sextant.

Results

Concentrations expressed in millimoles/kg are shown in table 1. Normal PZ has a higher Cit concentration than CG, although its level appears to fall off towards the apex. tCho concentrations are similar in PZ and CG despite slightly higher values in the former. BPH within the central gland exhibits a Cit level similar to that of PZ, whilst its tCho content appears to exceed that seen in PZ. As expected, large variations in Cit are found in PCa, with mean concentrations as low as 2 mmoles/kg found in some patients. However, surprisingly, the variations in tCho are much less spectacular and absolute values of tCho in PCa overlap with those estimated in all the other prostatic tissues.

Table 1		Base	Midgland	Apex
Normal PZ	Cit	34.5 ± 3.4	33.6 ± 3.9	27.4 ± 3.5
	tCho	5.9 ± 1.9	4.0 ± 1.3	3.9 ± 0.9
CG	Cit	22.8 ± 2.4	19.4 ± 1.3	15.6 ± 1.1
	tCho	4.3 ± 0.9	3.4 ± 0.8	3.3 ± 0.6
BPH	Cit	33.9 ± 2.2	34.2 ± 4.5	32.7 ± 5.5
	tCho	6.9 ± 1.2	7.1 ± 2.1	6.7 ± 1.9
PCa	Cit	6.7 ± 4.1 (range 2.1 – 14.3)		
	tCho	5.8 ± 2.9 (range 2.3 – 7.5)		

Discussion

We have estimated absolute concentrations of tCho and Cit in the prostate, and in agreement with results from the literature, we have observed significantly higher Cit in PZ than in CG tissue. In PCa, the anticipated reduction in Cit was not accompanied by an equally important increase in tCho – this would suggest that increases in tCho/Cit type ratios are primarily due to loss of Cit and not due to a sharp rise in tCho. It is worth noting that the higher Cit in BPH will allow a more easy differentiation with respect to CG.

Conclusion

In the context of treatment by hormonotherapy and radiotherapy, and its eventual follow-up, this absolute quantification approach will allow a more precise and thorough assessment of choline concentration in the prostate by avoiding misleading effects on tCho/Cit when the citrate concentration tends to zero.

References

(1) G. Liney et al., NMR in Biomedicine, 9, 59-64, 1996.