Characterization of prostate cancer by quantitative MRI

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Introduction.

Quantitative estimates of the baseline physiology and MR characteristics of the prostate may help to predict the response of the gland to treatment. The purpose of this study was to assess these characteristics in the pathological prostate gland prior to treatment with external beam radiotherapy using T_1 and T_2 mapping, dynamic contrast-enhanced MRI and a distributed parameter tracer kinetic model. The hypothesis to be tested is that these characteristics will serve as sensitive indicators of tissue response to treatment and thereby provide a useful prognostic tool.

Methods.

Twenty-two men with histologically proven adenocarcinoma of the prostate were recruited into the study. The Local Research Ethics Committee approved the study and written consent was obtained from all men. Histological diagnosis was obtained by transrectal ultrasound guided biopsy in 21 and from tissue obtained at the time of a transurethral resection of the prostate in one. The clinical stage at presentation was T1c – T3b. All men had a negative isotope bone scan. The mean Gleason score was 6 (range, 5 - 8); mean PSA 27.5 ng/ml (range, 6 - 74 ng/ml) and mean age 67 years (range, 57 - 76 years). These patients all selected external beam radiotherapy for subsequent treatment of their disease. The patients were scanned on a 1.5 T Philips MR system using a pelvic phased-array coil. T_2-weighted fast spin echo images of the entire gland were acquired using a TR of 4.75 s at echo times of 7, 45, 100 and 240 ms to estimate baseline T_2 [1]. A 3D T_1-weighted gradient echo pulse sequence was used at flip angles of 2º, 10º, 20º and 30º to estimate baseline T_1 [2]. This was followed by a dynamic series in which volumes (flip angle 30º) were acquired every 2.3 s for approximately 4 minutes. Early in this series 0.1 mmol/kg Gd-DTPA-BMA was injected at 3 ml/s using a power injector.

The image data were subsequently analysed off-line. For each patient regions of interest were drawn in the external iliac or femoral arteries (to provide a vascular input function). With the aid of T_2-weighted images a radiologist (CEH) drew further regions in prostate tumour, muscle (internal obturator) and, where possible, normal contralateral peripheral zone. For each region estimates of T_1 and T_2 were made and signal intensity variations were converted to temporal changes in Gd-DTPA-BMA concentration [2] and a distributed parameter model [3] was fitted to the data.

Results.

Analysis of the data from each region provided estimates (mean ± SD) of T_1, T_2, blood flow (F), blood volume (V_b), microvascular permeability-surface area product (PS) and interstitial volume (V_e) [4].

Tissue	T_1 (ms)	T_2 (ms)	F (ml/100 ml/min)	V_b (ml/100 ml)	PS (ml/100 ml/min)	V_e (ml/100 ml)
Tumour (n=22)	916 ± 298	93 ± 15	66 ± 43	1.0 ± 1.4	22 ± 12	42 ± 20
Normal (n=20)	962 ± 273	131 ± 27*	32 ± 36*	1.5 ± 2.4	21 ± 24	27 ± 10*
Muscle (n=22)	1026 ± 242	52 ± 8*	9 ± 7*	1.8 ± 2.0	5 ± 5*	12 ± 17*

*Significantly different from tumour values using the non-parametric Wilcoxon Signed Ranks test ($p<0.01$).

Discussion.

Our estimates of the relaxation times compare well with previous results and underscore the drop in T_2 seen in cancer [1]. This analysis was based upon estimates of T_2 made using only the first three echoes. There was an indication of the multiexponential T_2 behaviour reported by Kjaer et al. [5] when the 240 ms echo data were considered and this finding requires further study.

The results of the tracer kinetics analysis confirm that blood flow to tumour tissue exceeds that to normal prostatic tissue but that the difference in blood volume is insignificant [6]. Similarly, the interstitial distribution space in the tumours is enlarged [7] but no difference between the permeability-surface area products of tumour and normal microvessels was detectable. In a recent publication reporting the use of contrast-enhanced CT and the same tracer kinetics model the authors stressed the importance of interpreting results with caution since the precision of parameter estimates can be low [8]. Indeed, the estimates of PS made in this study were not always reliable; PS cannot be estimated when the contrast agent is completely extracted on its first pass (E = 1). The blood volume estimates reported by Henderson et al. [8] were larger than found in this study and may reflect MR-specific problems associated with transendothelial water exchange [9] in addition to the difficulties previously experienced in fitting complex models [4]. However, MR studies such as this have distinct advantages over CT studies. The exquisite soft tissue contrast of T_2-weighted images allows for the analysis of hypointense regions against normal-appearing peripheral zone in any part of the gland. The radiation burden of the dynamic CT study prevents the examination of more than one or two sections and these must be chosen with little prior knowledge of the location of cancer. MR may be used repeatedly; further studies are ongoing with patients returning for follow-up MR scans 12 months after treatment. These findings show considerable promise for isolating both the MR and physiological characteristics of prostate cancer and may help to assess tissue response to treatment in this and future studies.

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