Dynamic Contrast Enhanced Imaging and Quantitative Analysis of Prostate Cancer at 3 Tesla

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INTRODUCTION: Endorectal coil MRI of the prostate has been extensively studied at 1.5T for detecting and staging prostate cancer. Typically, T2-weighted scans are supplemented by MR spectroscopy or Dynamic Contrast Enhanced (DCE) MRI in order to improve the specificity of the examination. The potential advantage of 3.0T MRI is higher signal to noise ratios leading to higher spatial and temporal resolution .Whether these result in superior diagnostic performance is still an open question. The purpose of this study was to evaluate the sensitivity and specificity of high resolution T2 weighted MRI and DCE-MRI parameters calculated from signal intensity-time curves at 3.0T using a two compartment pharmacokinetic model.

MATERIALS AND METHODS: This study included 36 consecutive patients with biopsy proven prostate cancer (age range 53-77, mean age 63) that underwent imaging of the prostate at 3.0 T between February 2005 and October 2005. The study was approved by our Institutional Review Board and informed consent was obtained from each patient. All of the imaging was performed on a Philips Intera 3.0 T scanner (Philips Medical System, Best, The Netherlands) with an endorectal coil (BPX-15; Medrad, Indianola, PA) tuned to 127.8 MHz and combined with the Philips SENSE cardiac coil. After digital rectal examination, the endorectal coil was inserted and inflated with Fluorinert (3M, St. Paul, MN) to a volume of approximately 60 ml. T2-weighted (T2W) turbo spin-echo images were obtained in 3 planes at a resolution of 0.46 x 0.6 x 3.0 mm (FOV 140 mm, matrix 234 x 304, TR/TE 8852/120 ms) **(Fig 1).** DCE images were acquired during a single dose injection of Gd-DTPA (Magnevist; Berlex Laboratories, Wayne, NJ) at a rate of 3 ml/sec with an injector (Spectrix MR Injection System; Medrad, Pittsburg, PA) **(Fig 1)**. The DCE acquisition consisted of a 10 slice 3D fast field echo with a temporal resolution of 3.1 sec with TR/TE of 5.5/2.1 ms, 15º flip angle, 26 cm FOV, effective SENSE factor of 2 and resolution of 0.86x1.18x6.0 mm. The arterial input function was obtained from the dynamic series by averaging voxels from an ROI in the femoral artery. A pre-contrast T1 map was calculated with a two flip angle approach by acquiring an identical 3D acquisition with a flip angle of 5º to use along with the pre-contrast data from the dynamic acquisition.

A two compartment general kinetic model (GKM) based on Kety equations implemented in the Philips Pride programming environment under IDL (RSI, Boulder, CO) yielded the following DCE-MRI parameters: K^{trans} (volume transfer constant, min^{-1}), k_{ep} (flux rate constant between extravascular extracellular space [EES] and plasma, min^{-1}) and v_e (the volume of EES per unit volume of tissue). Color maps based on these parameters were generated **(Fig 2)**. Based on anatomic landmarks on axial T2W images, the prostate gland was divided into sextants: left and right apex, middle gland and base. Each sextant was analyzed separately based on DCE-MRI, T2-weighted images and quantitative kinetic parameters. Imaging findings were histologically verified from biopsy samples.

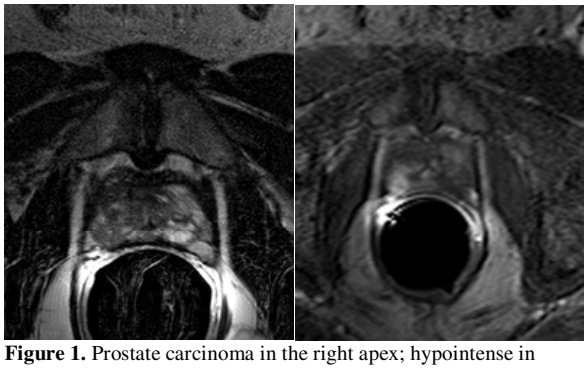

Figure 1. Prostate carcinoma in the right apex; hypointense in the T2W image and early enhancement in DCE-MRI.

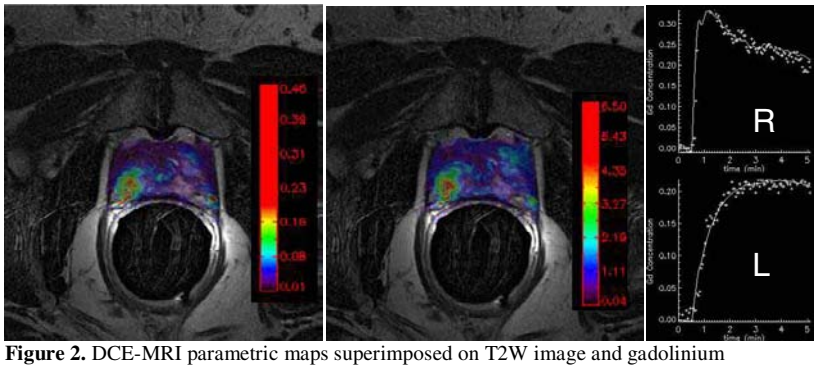

Figure 2. DCE-MRI parametric maps superimposed on T2W image and gadolinium concentration-time curves in malignant (right side) versus benign prostatic tissue.

RESULTS: Pathologically confirmed cancer areas in the peripheral zone of the prostate were characterized by low signal intensity on T2W, early enhancement and/or early wash-out in dynamic images. The overall sensitivity, specificity, positive predictive value, and negative predictive value of T2W was 98%, 30%, 40%, 97% respectively. The sensitivity, specificity, positive predictive value, negative predictive value of DCE-MRI were 76%, 78%, 57%, 86%, respectively. When T2W and DCE-MRI were combined the sensitivity was 77%, and specificity was 78%. The mean value of tumor K^{trans}, k_{ep}, v_e for all sextants calculated from Gd-DTPA concentration time curves were 0.5 ± 0.4, 1.3 ± 0.8, 0.4 ± 0.2, respectively. The mean value of benign prostatic tissue K^{trans}, k_{ep}, v_e for all sextants calculated from Gd-DTPA time curve were, 0.2 ± 0.2, 0.8 ± 0.4, 0.2 ± 0.1. The mean K^{trans}, k_{ep}, v_e value for inflammation were 0.4 ± 0.3, 1.2 ± 0.7, 0.3 ± 0.2.

CONCLUSIONS: Endorectal coil MRI of the prostate at 3T produces qualitatively better T2W than 1.5T images (1) and thus, better defines the extent of tumors. Clinical results at 1.5 T vary in sensitivity and specificity from 51-89% and 67-87% respectively (2). In our study sensitivity of T2W was high but it should be noted that chronic prostatitis, post-biopsy changes and benign prostatic hyperplasia in the peripheral zone resulted in a high false positive rate with a specificity of only 30%. However the specificity of T2W improved from 30% to 78% with the addition of DCE-MRI. In comparison to prior studies performed at 1.5 T, the 3.0 T MRI does not significantly improve sensitivity and specificity in our study population; however the improved anatomic detail of the 3.0 T images justifies its use for pre-treatment mapping. MRI is inherently limited by inflammation, post-biopsy changes and hemorrhage which produce non-specific signal changes on both T2W, and DCE-MRI regardless of field strength. However, the addition of MR spectroscopy (MRS) and analysis of the pharmacokinetic GKM parameters may further improve the results achieved at 3.0 T. Pharmocokinetic GKM parameters provide insight into tumor pathophysiology: High k_{ep} values correlates with short residence time of contrast agent, and high K^{trans} with rapid arrival of contrast agent to tissues, and v_e corresponds to leakage space (3). To the best of our knowledge, this study contains the largest patient population on clinical prostate cancer study at 3.0 T and analyzed with GKM. Although K^{trans}, k_{ep}, ve, values were significantly higher in biopsy-proven cancer area than in normal peripheral zone, our attempt to determine parameter cut-offs for cancer, inflammation and benign tissue, was complicated by the considerable overlap in these parameters. A comprehensive statistical analysis to determine a classification scheme using a combination of the T2W, GKM DCE-MRI and MRS parameters to improve diagnostic accuracy is in progress.

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