Prediction of Treatment Response in Head and Neck Cancer Using DCE-MRI

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Introduction

The role of dynamic contrast enhanced (DCE)-MRI in detection and monitoring treatment response has been reported previously (1,2). However, to date there has been only a limited number of reports on the use of DCE imaging as a predictor of therapeutic response based on pre-treatment values (3,4). Furthermore, the efficacy of using the shutter-speed model (SSM) (5) to predict treatment response in human cancer has not been reported. Thus, the purpose of our study was to evaluate the feasibility of using DCE-MRI data with SSM analysis to predict response to chemoradiation therapy in HNSCC.

Materials and Methods

DCE-MRI data was acquired using a fast 3D spoiled gradient-echo sequence, which was modified to acquire eight angle-interleaved sub-aperture images from the full-echo radial data. The imaging parameters were: 256 readout points/view, 256 views (32 views/subaperture, 8 subapertures), FOV = 26 cm, slice thickness = 5 mm, 8 axial slices, flip angle = 20°, receiver bandwidth = 260 Hz/pixel, TR = 8.9 ms, and TE = 3.9 ms, fat saturation was applied once in every 8 excitations. Spatial saturation was applied once every 32 excitations to minimize the flow effect while minimizing the scan time. The scan time of full resolution data was about 20 s with fat and spatial saturations (2.5 s temporal resolution for each sub-aperture image). Baseline pre-injection images were acquired for 1 minute. A single dose of Gd-DTPA (0.1 mM/kg body weight) was injected at 1 mL/s into an antecubital vein, followed by saline flush with a power injector, during which scanning was continued for another 9 minutes. Image reconstruction and data analysis using SSM were performed using in-house software written in IDL. Pre-contrast T1 was estimated using inversion recovery prepared turbo FLASH sequence with 5 inversion times; 0.06, 0.2, 0.4, 0.8, and 1.6 s.

MRI data was acquired from thirty two patients who were newly diagnosed with HNSCC with no prior treatment and were referred for pre-operative chemo/radiation therapy. The MRI study was performed using a 1.5T Siemens Sonata scanner (n=24) and a 3T Siemens Trio scanner (n=8). Since the pharmacokinetic parameters are magnetic field independent, the SSM parameters estimated from the patients scanned at both scanners were combined together for this study. All patients had palpable metastatic cervical lymph node masses. The patients were categorized as complete responders (CR, with no evidence of disease), or partial responders (PR, with evidence of residual disease) based on clinical or pathological (if surgery was performed) assessment at the end of chemo-radiotherapy. The institutional review board approved this study, and written informed consent was obtained from all subjects before the scans. The difference in pharmacokinetic parameters between the two groups of patients was tested using Mann Whitney U Test with 95% significance level.

Results and Discussions

The SSM parameters derived from the pretreatment DCE-MRI data are shown in Fig.1. Pre-treatment values of K^{trans} from CR patients were significantly ($p < 0.05$) higher than that of PR. Since K^{trans} represents permeability as well as perfusion, this finding substantiates that the tumor with better perfusion and oxygen availability, as in CR responds to chemoradiation therapy as opposed to PRs, who demonstrate poor perfusion. The estimated EES volume fraction, v_e, did not show any significant difference between CR and PR as depicted in Fig.1b. The intracellular lifetime, t_i is shown in Fig.1c. Once again, pretreatment t_i values from CRs were significantly ($p < 0.05$) higher than PR. Among the three DCE parameters generated by SSM, K^{trans} showed the most significant difference between CR and PR. The common sensitivity and specificity for K^{trans} was ~75% with a cutoff value of 0.3 min^{-1}.

The SSM parameters were combined to test if they could classify the patients into CR and PR groups based on the pre-treatment parameters. Since we have only a small cohort of patients, we did not attempt to divide them into a training set and a test set. Instead, all data were used to obtain an optimal decision tree, which was then tested using a cross-validation method using randomly chosen sub-samples. The pretreatment DCE-MRI data were available from 32 patients of which 8 were PR and 27 were CR. Using a decision tree shown in Fig.1d, we found that when K^{trans} and v_e are used, we get a sensitivity of 100% and a specificity of 75% of this approach in differentiating PRs from CRs. The cutoff values used in this approach are shown next to the parameters.

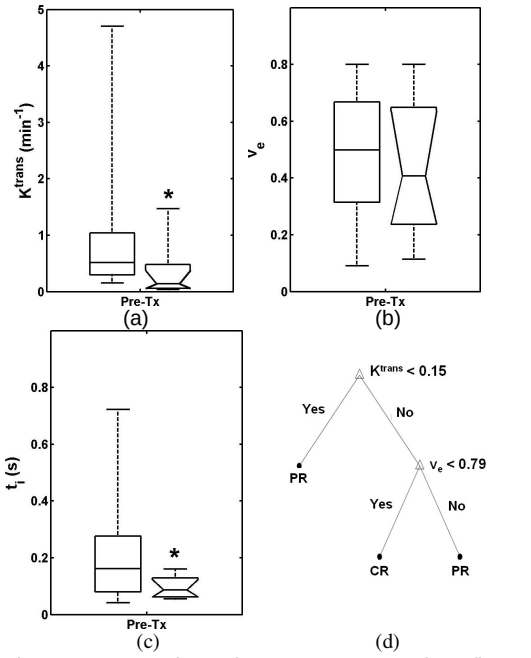

Figure 1: Comparison of SSM parameters of CR (box without notch) and PR (box with notch) (a,b, and c). * indicates significant differences ($p < 0.05$) between CR and PR. (d) a decision tree based on pretreatment SSM parameters.

Reference

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