MRI multi-parametric response mapping for assessment of early therapeutic efficacy in head and neck cancer

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Introduction

The therapeutic efficacy within a tumor can be evaluated by constructing MRI parametric response maps (PRM) on a voxel-by-voxel basis. By registering the pre-treatment and early-response image changes in individual voxels, these changes can be quantified for treatment evaluation. For early response, this approach may be more sensitive for assessing therapeutic efficacy than simple summarizing measurements such as the mean changes in individual biomarkers. Both ADC (apparent diffusion coefficient) and K^{trans} (volume transfer constant) have been successfully employed for monitoring treatment-induced tissue alteration in selected cancers [1-3]. It may be unrealistic to expect a single parameter to track all the different changes occurring at the cellular level within a tumor during therapy. Multiple parameters such as ADC, K^{trans} and T2 values (transverse relaxation time), may have their advantages in evaluating therapeutic efficacy. This study proposes to develop a multi-parametric response mapping (mPRM) method by combining DWI, DCE MRI and T2 mapping in head and neck (HN) cancers.

Methods

MRI data acquisition: MR data acquired from five HN cancer patients with metastatic nodes (age: 44-62 years, M/F: 5/0, primary cancer: 3 tonsil, 2 nasopharynx) was included in this retrospective study approved by the institutional review board. Pretreatment and early-response MRI scans including DWI, DCE-MRI and T2 imaging were conducted on same GE 1.5T Excite scanner, same coil and imaging protocol. The time between pre and early-response studies was 10-14 days. Patients were stratified by a short term response assessment at 3-4 months after completion of treatment into complete response (CR), and partial response (PR) as defined by the WHO response criteria [4]. MRI acquisition parameters that were constant included: field of view = 20-26mm, slices= 4-6, thickness = 4-8mm depends on tumor sizes. For DWI images, a single-shot echo planar imaging spin echo sequence was used with multiple b values (b=0, 50, 100, 250, 500, 750, 1000, 1500 s/mm^2), TR = 3000 ms, TE= minimum. For DCE-MRI images, a 2DSPGR pulse sequence was used, the contrast of Gd-DTPA was delivered at a bolus of 0.1 mmol/kg and 2 cc/s, TR = 7.8 ms, TE=1.9 ms, temporal resolution = 3.75-7.5 seconds. For T2 images, a 2D spin echo sequence with 4 echo times was used.

Multi-parametric response mapping (mPRM): A nonrigid image registration algorithm based on B-spline free form deformation method was performed on the acquired pre-treatment and early-response weighted images [5]. Parameters (ADC, T2, K^{trans}) were quantified from the registered images. Voxelwise response for each parameter was determined by calculating the change in parameter value between pre-treatment and early-response. For ADC, the response was labeled positive when ΔADC >0, negative when ΔADC <0; For T2, the response was positive when ΔT2 >0, negative when Δ T2 <0; for K^{trans}, the response is positive when Δ K^{trans}<0, negative when Δ K^{trans}>0. Parametric response was defined unanimously positive when all 3 parameters had positive change in the parameter value (termed pUP, red voxels overlaid on T1W images see Fig 1, 2); parametric response was unanimously negative when all of the parameters had negative change (termed pUN, blue voxels); and the parametric response was defined mixed when it showed both positive and negative changes (termed pM, green voxels). Parametric responses for all voxels were calculated to develop a multi-parametric response map. The percentage of voxels belonging to pUP, pUN and pM were also calculated.

Results

Out of the five patients; three patients demonstrated CR and two demonstrated PR. Figure 1 and 2 display images from two representative patients who were CR and PR respectively.The parametric response indices for a patient with CR were: pUP=93%, pUN=7% (from PRM_{T2}); pUP=89%, pUN=11% (from PRM_{ADC}); pUP=59%, pUN=41% (from PRM_k^{trans}); pUP=48%, pM=51%, pUN=1% (from $mPRM_{T2+ADC+K}^{trans}$). In comparison, the parametric response indices for a patient with PR were: pUP=64%, pUN=36%(from PRM_{T2}); pUP=91%, pUN=9% (from PRM_{ADC}); pUP=51%, pUN=49% (from PRM_k^{trans}); pUP=27%, pM=71%, pUN=1%. (from $mPRM_{T2+ADC+K}^{trans}$). There were no major difference for pUP and pUN from PRM_{ADC} for patients demonstrating PR or CR because for both patients PRM_{ADC} changes were significant (pCR=89%, pCR=91%, respectively) after treatment. On the other hand, $mPRM_{T2+ADC+K}^{trans}$, incorporating information from T2 and K^{trans}, revealed that the value of pUP (=27%) in PR patient was much lower than in CR patient (pUP=48%), showing that more voxels didn't respond to the treatment in PR patient.

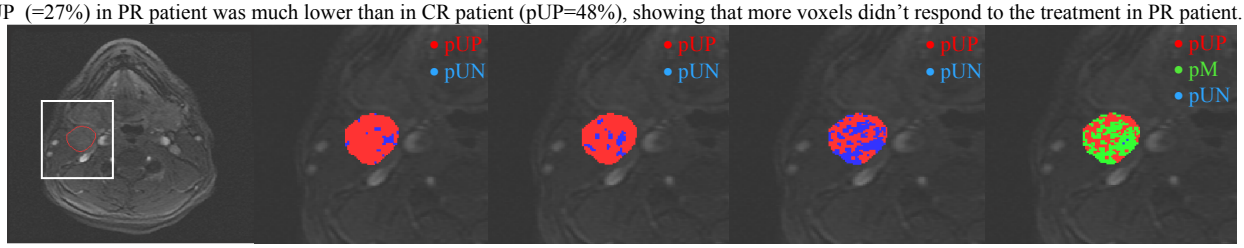

Fig 1. mPRM for a CR patient. From left to right, pretreatment contrast enhanced T1W image with box highlighting the area magnified in the subsequent images, zoomed PRM_{T2}, PRM_{ADC}, PRM_k^{trans},and $mPRM_{T2+ADC+K}^{trans}$.

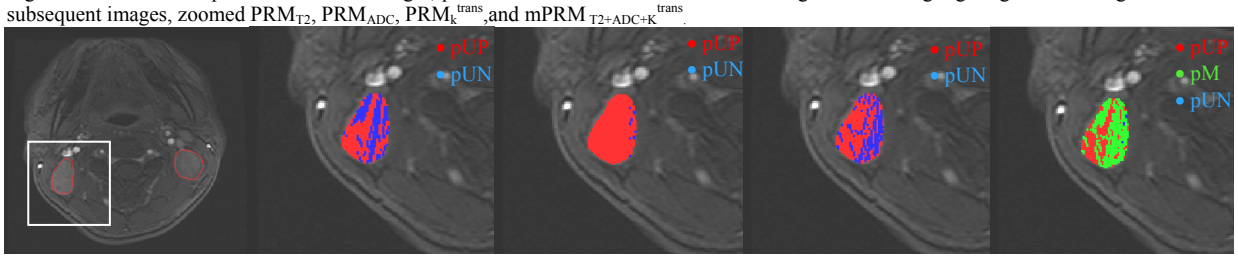

Fig 2. mPRM for a PR patient. From left to right, pretreatment contrast enhanced T1W image with box highlighting the area magnified in the subsequent images, zoomed PRM_{T2}, PRM_{ADC}, PRM_k^{trans}, and $mPRM_{T2+ADC+K}^{trans}$.

Discussion and Conclusion

This study provides a tool to evaluate spatial therapeutic efficacy using multiple MR parameters. Compared to average value of parameters such as ADC and K^{trans}, PRM has shown its promise in treatment diagnosis and prognosis [1-3]. However, from our study, PRM_{ADC} seems to be too sensitive to treatment related changes and mPRM incorporating information from ADC, T2 and K^{trans} provides better assessment of therapeutic efficacy on a voxel by voxel basis. mPRM may provide more comprehensive and accurate information than the use of a single parameter for early assessment of treatment response.

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References

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