Diffusion-weighted and dynamic contrast-enhanced imaging at 3.0 T of prostate cancer

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Introduction

Identifying the location and extent of tumors inside the prostate allows boosting of the radiation dose during radiotherapy treatment. The purpose of this study is to improve the accuracy in localizing and delineating gross tumor volume (GTV) within the prostate, using a combination of anatomical and functional (diffusion-weighted and dynamic contrast-enhanced) imaging at 3.0 T.

Methods

DCE-MRI and DWI scans were made of 6 patients with biopsy proven prostate cancer (1 patient T1c, 5 patients T3, all N0M0). The location of the tumor was identified by rectal digital examination, transrectal ultrasound imaging and biopsies. DWI scans were performed using a fat suppressed (SPIR) single shot EPI sequence (TE 60 ms, TR 2500ms, 24 slices (3 mm), 2.5 mm in plane resolution, using b values of 0, 500 and 1000 s/mm^2. Apparent Diffusion Constants (ADC) were estimated from these three data points (In a first approximation, effects of the other gradient pulses in the pulse sequence have been ignored). Volumes consisting of contiguous voxels with an ADC<1.0 10^{-3} mm^2/s were identified. Volumes smaller than 1cm^3 were ignored in this study.

For DCE-MRI 10 slices were scanned simultaneously and this 120 times at 2.4 s interval. At the start we injected 8 ml of gadolinium DTPA contrast in 10 seconds, followed by a saline flush. To obtain quantitative results we calculated the concentration of the contrast agent from the MR signal using preceding small flip angle scans with 3 flip angles. For each voxel the concentration-time curves are analyzed using a distributed tracer kinetics model, yielding a quantitative 3D map of blood flow parameters. Volumes consisting of contiguous voxels with a flow > 20 ml/100g min were identified and volumes smaller than 1 cm^3 were not further considered.

Results

The six patients all showed a single volume larger than 1 cm^3 with ADC < 1.0 10^{-3} mm^2/s. Smaller volumes could be identified, but were ignored from further analysis. The average ADC inside the volumes was 0.82 10^{-3} mm^2/s (range 0.74 – 0.8810^{-3} mm^2/s). The volume size was on average 8.1 cm^3 (range 2.6 – 11.6 cm^3). The ADC in the prostate, excluding the low-ADC regions, was on average 1.3 10^{-3} mm^2/s (range 1.24 – 1.370 10^{-3} mm^2/s). The patients also showed a single volume larger than 1 cm^3 exceeding the flow threshold. The average flow in these regions was 29.3 ml/100g min (range 23.6 – 32.7 ml/100g min). The flow in the prostate, excluding the high-flow regions, was on average 14.1 ml/100g min (range 10.1 – 19.0 ml/100g min).

The Dice similarity coefficient is defined as 2n(a+b)/(n(a)+n(b)) and reflects the overlap between two volumes a and b, with n the number of voxels in the volume. For all T3 staged patients the average was 0.32, (range 0.22 to 0.43). The location of the combined low-ADC and high-flow area corresponded to the location of the tumor as determined clinically. The T1c staged patient showed no overlap between low-ADC and high-flow region. For this patient the tumor was not palpable or observable on ultrasound, with a positive biopsy on the left side.

Discussion and conclusion

Low ADC values are thought to reflect a high cell density, limiting the free water diffusion[1], whereas high blood flow correlates with micro-vessel density[2]. Both features are indicative for tumor tissue inside the prostate. However, our data show a partial overlap between low ADC and high flow regions, suggesting that simultaneous diffusion and perfusion imaging provides complementary functional data that can be used in the pre- and post therapeutic disease manangement in prostate cancer patients.

[1]B.D. Ross *et al.* Mol. Cancer Ther. 2:581-587 (2003); [2]T.-Y. Lee, *et al.* QJ. Nucl. Med. 41:171-187 (2003)

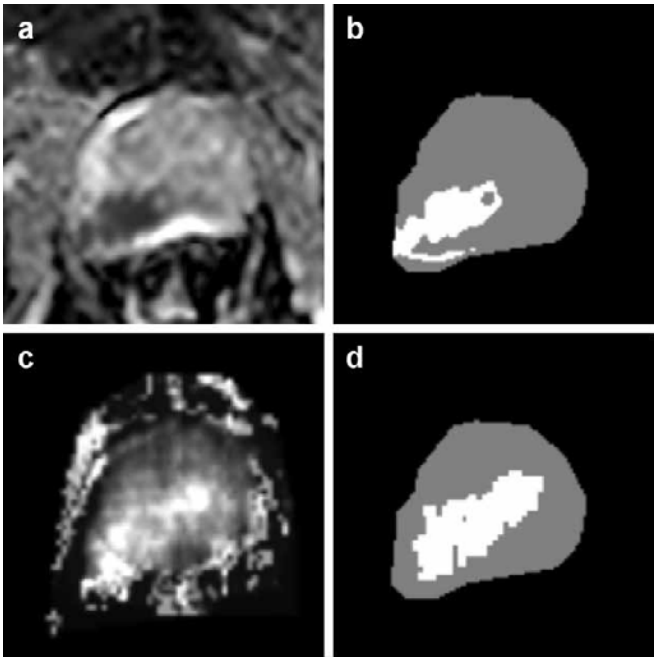

figure 1: the ADC is plotted for one patient (a), with the low-ADC region (b), the blood flow (c) and the high-flow region (d).

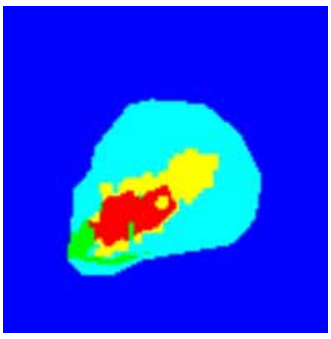

figure 2: the overlap between low-ADC and high-flow region, with light-blue: prostate, green: low-ADC only, yellow: high-flow only, red both low-ADC and high-flow.