Multi-b-value diffusion weighted imaging acquired on a 3T MR scanner: comparison of the apparent diffusion coefficient in prostate cancer detection and the contribution of b-value images in ADC map interpretation.

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Introduction

The diffusion-weighted MR sequence (DWI) represents the major component of the multiparametric MR examination in prostate cancer detection. The influence of flow sensitive b0 images on the ADC maps of the prostate for cancer detection was assessed by comparison of ADC maps obtained with and without the b0 image in order to obtain flow-sensitive and flow-insensitive ADC maps. The second question considers whether a multi-b ADC map calculated from b0-b500-b1000-b1500 s/mm^2 performs better than a 2-b ADC map from b0 and b1500. In each case, the contribution of each b-values in addition to the ADC alone was assessed in the performance estimation.

Methods

Consecutive patients scheduled for a prostatectomy and scanned on a 3T PET-MRI with a protocol including a standard EPI diffusion sequence using b-values of 0-500-1000-1500 s/mm2 were searched retrospectively from our database. The b-value images were normalized using the internal obturator muscle signal intensity. A monoexponential model was fitted to obtain the ADC maps computed using the different b-values combination. In a first step, ADC maps were computed with all 4 b-values (flow-sensitive ADC) and after exclusion of the b0 data (flow-insensitive ADC). In a second step, ADC maps using 2 b-values (with the b0-b1500) and 4 b-values (with b0-500-1000-1500) were also computed. The whole prostate and the cancer foci were segmented to label each voxel of the prostate volume as normal or tumoral based on the histological slides. In a univariate analysis, differences between tumor and normal values for each parameter were assessed for significance using non-parametric Wilcoxon rank sum tests computed by using the median value obtained from each patient. A ROC curve is built for each parameter and the AUC computed. In a multivariate analysis, a logistic regression model was fitted and the ROC curve computed. After stepwise parameter (deviance based) selection of the b-values in addition to the ADC maps, ROC curves were computed for a model built from 4 b-values (LR4-adc-b) and from 2-b values (LR2-adc-b). The parameter alone and their combination in a logistic regression model were compared using the AUC. The AUC were compared using a test based on Delong methods.

Results

19 patients were retrieved and one was excluded because of artifacts due to a hip prosthesis, therefore 18 patients were selected. Each prostate segmentation produced a total of 126400 prostatic voxels (voxels per patient: mean 7022, standard deviation 3577) with 8876 tumoral voxels. The Wilcoxon test on the median distribution between the normal and tumoral voxels was not significant for b0 only. For the other b values and the ADC, the difference between tumoral versus normal voxels is significantly different. Among the ADC maps (figure 1), the 4-b flow-sensitive ADC map performed better than the 3-b flow-insensitive ADC map with an AUC at 0.8497 versus 0.8158 ($p<0.001$). Furthermore, the 4-b ADC map fitted from the b1500-b1000-b500-b0 was not significantly better than the 2-b ADC map fitted with the b1500-b0 ($p=0.6$). In multivariate analysis, the logistic regression model built from 4 b-values and the corresponding ADC (LR4b, AUC=0.8962) performed equally well to the model obtained from the 2 b-values b1500-b0 and the corresponding ADC (LR2b, AUC=0.8942) without significant difference ($p=0.4872$). The ROC curves of both models are illustrated in figure 2. Comparing the ADC alone with the logistic regression model, which incorporates the b-values, the adjunction of the b-values improves cancer detection with an AUC increasing from 0.8497 to 0.8962 for the 4-bADC versus LR4b ($p<0.001$) and from 0.8481 to 0.8942 for the 2-bADC versus LR2b ($p<0.001$).

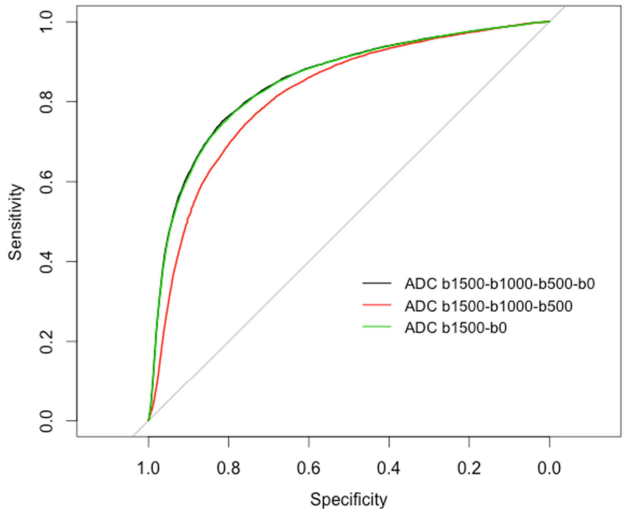

Figure 1 *Comparison of ADC maps. The flow-sensitive ADC obtained from 4-b values (b1500-b1000-b500-b0) was plotted and corresponds to the best performing ADC map with an AUC at 0.8497. Such a map is significantly better than the flow-insensitive 3-b ADC map obtained form the b1500-b1000-b500 providing an AUC at 0.8158 ($p<0.05$). However, the ADC map obtained from 2-b b1500-b0 was not significantly lower with an AUC at 0.8481 ($p=0.6127$).*

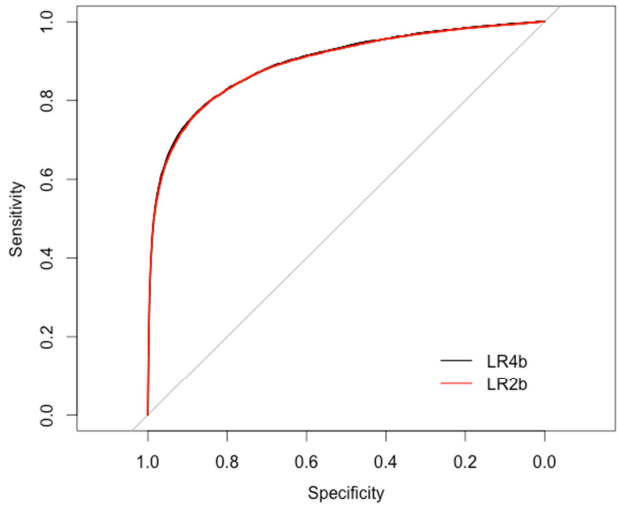

Figure 2 *Comparison of the ROC curves of the logistic regression models using the b-values and the ADC as covariates. In the LR4b, the model included the b1500-b1000-b500-b0 and the corresponding 4-b ADC and provided an AUC at 0.8962. In the LR2b, the model included the b1500-b0 and the corresponding 2-b ADC and provided an AUC at 0.8942. The curves are completely similar without significant difference ($p=0.4872$).*

Discussion and Conclusions

This study has demonstrated that the flow-sensitive ADC map was superior to the flow-insensitive ADC map for prostate cancer detection. The b-value images provide complementary information to the ADC map and improve over the ADC map alone in cancer detection. This study provides a statistical demonstration of this commonly accepted practice to look for enhanced signal in cancer on the high b-values images in the area of reduced ADC. Furthermore, the realization of a multi-b ADC maps in comparison with a 2-b ADC map did not improve the performance of the diffusion-weighted imaging.