Comparison of Unidirectional Diffusion Weighting with Isotropic Diffusion Weighting for the Detection of Prostate Tumors.

M. E. Philippens[1], T. Takahara[2], G. Groenendaal[1], and U. A. van der Heide[1]

[1]Radiation Oncology, University Medical Centre Utrecht, Utrecht, Netherlands, [2]Radiology, University Medical Centre Utrecht

Introduction: Diffusion weighted imaging is a powerful tool for the diagnosis of prostate cancer. In radiotherapy, delineation of the tumor for dose escalation is an important issue. Therefore, clear tumor boundaries have to be distinguished. In tumors, the diffusion direction of water is thought to be isotropic. The fractional anisotropy in the peripheral zone and central zone is reported to be very low 0.1-0.2 [1,2] or intermediate 0.46-0.47 with a preferential direction in the superior inferior direction [3,4]. Generally, three axes of motion probing gradient are applied to calculate the apparent diffusion coefficient (as of trace image) to distinguish prostate cancer from normal peripheral or central zone. However, measurements with diffusion weighting in different directions can result in increased blurring of the images due to averaging of artifacts that originate from the gradient application in different directions in an SE-EPI sequence. Less blurring of the images enables reduction of the measuring time or increases the signal to noise. Therefore, both isotropic and unidirectional diffusion weighting was applied and the effect on the determination of prostate cancer was studied. To determine the blurring in unidirectional diffusion weighting with isotropic diffusion weighting for the detection of prostate tumors, the ADC of both diffusion weighted sequences is compared with respect to noise in the ADC values and anisotropy in both the entire prostate and regions with a low ADC values.
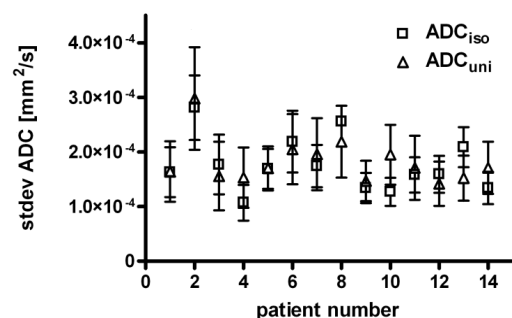

Figure 1. The standard deviations in the ADC map derived from the measurements with isotropic and unidirectional diffusion weighting (ADC$_{iso}$ and ADC$_{uni}$, respectively) of 14 different patients. No significant difference between the ADC values was found.

Material and Methods:

Fourteen patients with biopsy proven prostate cancer underwent an MRI on a 3T Philips Achieva MR scanner to determine prostate tumor localization for radiotherapy treatment. Three dimensional anatomical MR images were acquired using a balanced Turbo Field Echo (TR=2.85 ms, TE=1.42 ms, flip angle = 21, slice thickness=2 mm, matrix=512x512, FOV=250 mm, CLEAR, SPAIR). Two SE-EPI sequences were used with an TE=84 ms, EPI factor of 47, SENSE factor=2, half scan=0.6, 5 b-values (0, 300, 500, 1000, 2000 s/mm^2), slice thickness=3 mm, matrix=160/160, FOV =380 mm, for the isotropic DWI TR=5020 ms, NSA=3 and three diffusion directions (read, phase and slice) and for the unidirectional DWI TR=5369 ms, one diffusion direction (phase) and NSA=9. In other words, effective NSA (or scan time) is the same between isotropic DWI and unidirectional DWI.

Apparent diffusion coefficient (*ADC*) maps were generated from the DWI with 3 b-values 300, 500 and 1000 s/mm^2 (*b*) by a linear regression after a logarithmic transformation of the signal intensity (*lnS*), $lnS = A \exp(-b\ ADC)$, where A is the amplitude. The standard deviation of the fitted parameter values was assessed by propagation of the measurement errors. The prostate was delineated after manual registration of the balanced TFE and DW images to account for EPI distortions. Corresponding ADC values in the prostate were compared in a Bland-Altman plot. The standard deviation of the ADC values derived from the linear fit for both DWI methods were compared using a Wilcoxon signed rank test. The same method was used to compare the standard deviation deduced from the Bland-Altman plots with the standard deviation of the isotropic ADC (ADC$_{iso}$) and unidirectional ADC (ADC$_{uni}$) values. Low ADC values were selected using a threshold of 0.9 10^{-3} mm^2/s.

Results:

Although unidirectional diffusion weighting was hypothesized to result in less blurring and therefore less noise, the standard deviation in both images is similar (fig. 1). The standard deviation of the difference of the determined in the Bland-Altman plot was similar to the standard deviation of the individual ADC values.

The Bland-Altman analysis showed on average slightly higher values for the ADC$_{iso}$ than for the ADC$_{uni}$ with a mean bias of 0.07±0.07 10^{-3} mm^2/s (fig. 2). The standard deviation of the difference between ADC$_{iso}$ and ADC$_{uni}$ was similar to the standard deviations of the individual ADC maps. In the ADC$_{iso}$ map more low ADC values were found than in the ADC$_{uni}$; 457 and 300, respectively (fig. 3). Further, not all the regions with a low ADC values coincided. The standard deviation in the areas with low diffusion coefficients was similar to that in the whole prostate.

Discussion:

Blurring by averaging images with different diffusion directions was of minor importance for the noise on the ADC maps. The slightly higher values for isotropic ADCs might be due to anisotropy with a preferential diffusion direction in the craniocaudal direction as reported [3,4]. The standard deviation in the Bland-Altman plot can be explained by the standard deviation in the individual ADC maps. This might reflect the non-uniform anisotropy through the prostate and also in the regions with a low ADC values that can be attributed to patient motion and differences in susceptibility artifacts due to different pixel bandwidth in the phase encode direction. The lower number of pixels with a ADC value below a fixed threshold in the ADC$_{uni}$ map is in contradiction with the bias found.

Conclusion:

Unidirectional diffusion weighting did not lead to less noise in the ADC values compared to isotropic diffusion weighting for prostate imaging. Therefore, no benefit for measuring time or signal to noise is expected.

References: 1. Takayama JMRI 2008; 2. Xu Proc. ISMRM 2008; 3. Manenti Invest Radiol 2007; 4. Sinha, MRM 2004
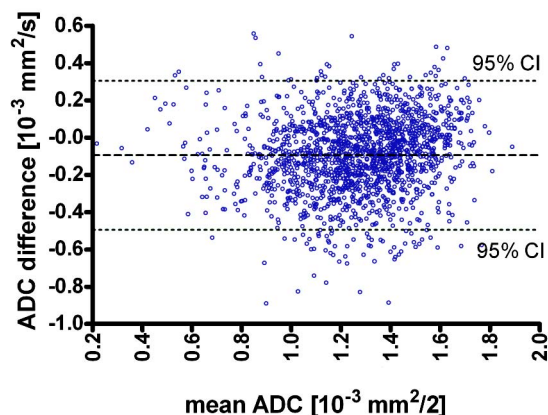

Figure 2. Bland-Altman plot of the ADC$_{iso}$ and ADC$_{uni}$ values in the all the prostate pixels of one patient. The ADC difference is calculated as ADC$_{iso}$-ADC$_{uni}$.
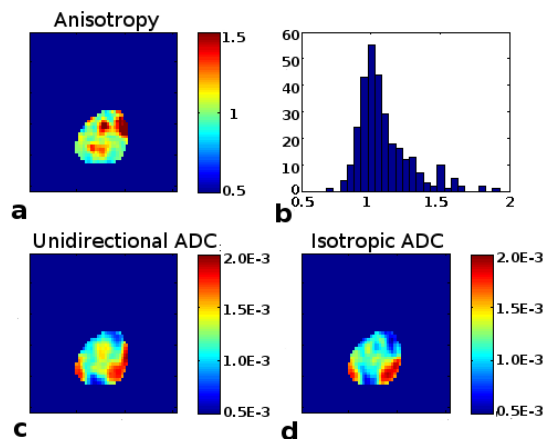

*Figure 3. Maps of the relative anisotropy (ADC$_{uni}$/ADC$_{iso}$) (**a**) with its histogram (**b**) and the ADC$_{uni}$ (**c**) and ADC$_{iso}$ (**d**) map. The anisotropy map shows several regions with higher ADC$_{iso}$ than ADC$_{uni}$. Anisotropy is present in regions with higher as well as with lower ADC values. The ADC$_{iso}$ map shows more pixels with low ADC values than the ADC$_{uni}$ map.*