B0-correction and k-means clustering for accurate and automatic identification of regions with reduced apparent diffusion coefficient (ADC) in advanced cervical cancer at the time of brachytherapy

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Objective

Diffusion Weighted MRI (DW-MRI) has shown great potential in diagnostic cancer imaging and may have value for monitoring tumor response during radiotherapy (RT). Patients with locally advanced cervical cancer are treated with brachytherapy (BT) using an intracavitary applicator with steep dose gradients making accurate delineation essential. Including DW-MRI in dose-planning of BT could improve target delineation and dose delivery to tumor. An important obstacle to be overcome is the pronounced sensitivity of EPI based DW-MRI to B0 inhomogeneity, leading to geometrical distortions which are further amplified due to the intracavitary applicator. This study evaluates the use of k-means clustering for automatic user independent delineation of regions of reduced apparent diffusion coefficient (ADC) and the value of B0-correction of DW-MRI for reduction of geometrical distortions during dose planning of BT.

Materials and methods

DW-MRI (b = 0, 150, 600, 1000 s/mm^2) was collected from ten MRI examinations of eight patients with locally advanced cervical cancer and with plastic applicator for BT in place. All MR examinations were performed using a 1.5T MRI (Magnetom Symphony, Siemens Erlangen, Germany). A GRE sequence with dual echo (TE = 4, 8ms) was used for calculation of B0 field map and corresponding pixel displacements used for correction in the phase-direction. Both non-corrected and B0-corrected DW images were resampled to match the T2W images used for dose contouring. To ensure non-biased detection of tumor tissue on DW-images, ROIs were created using user-independent k-means clustering (3 groups) with the b1000 images and ADC-maps (computed using b=150, 600, 1000 s/mm^2) as input. The match between the gross tumor volume (GTV) contour and the DWI ROI was evaluated as the percentage of DWI ROI inside the GTV and the Jaccard similarity index ((GTV $\cap$ DWI)/(GTV $\cup$ DWI)). The center of the tandem was marked on T2W images and non-corrected and B0-corrected DW images and the differences were compared.

Results

The percentage of DWI ROI inside the GTV was 67.1±10.6% (non-corrected) and 73.1±12% (B0-corrected) respectively. The B0-correction thus increased the overlap of DWI ROI and GTV volumes (Students paired t-test p = 0.011) with a mean improvement of 6.0±5.9%. The Jaccard similarity index was also improved (Students paired t-test p = 0.018) from 0.47±0.11 (non-corrected) to 0.52±0.13 (corrected). The difference in tandem center marked on T2W and DW images was 2.5±1.2 mm (non-corrected) and 1.3±0.9 mm (B0 corrected) showing a better spatial match for the B0-corrected DW images (Students paired t-test p = 0.039).

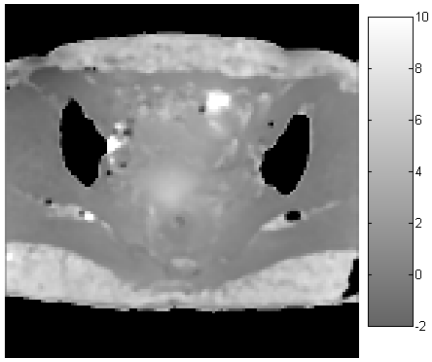
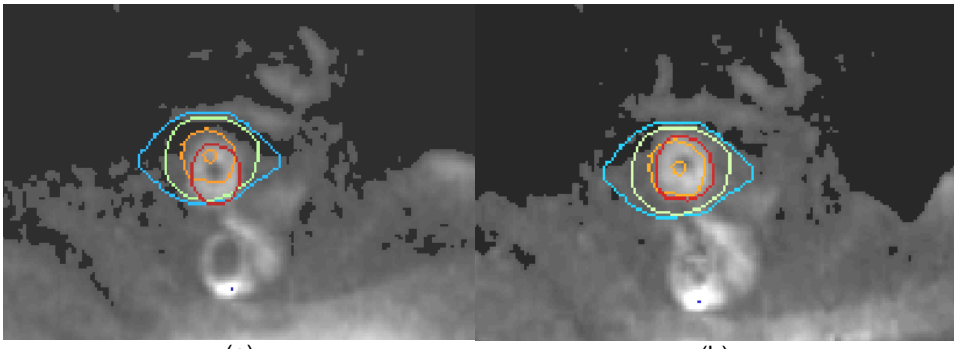


Fig. 1 Calculated displacement map [in pixels].



(a) (b)

Fig. 2 (a) Non-corrected DW image (b=1000 s/mm^2) **(b)** and B0-corrected DW image (b=1000 s/mm^2)**,** with dose-planning contours: GTV (orange), DWI ROI (red), high risk clinical target volume (CTV) (green), intermediate risk CTV (cyan). The small orange contour outlines the tandem center of the applicator.

Conclusion

The k-means clustering promises to be a solid method for user-independent delineation of regions with reduced ADC. Acquisition and calculation of field maps of BT-patients with applicator for BT in place is feasible. The B0- correction of the DW images significantly improves the similarity between the DWI ROI and the tumor contour (GTV) and also reduces the mismatch of the tandem center position compared to the T2W images. These results shows the benefit of correcting geometric distortions combined with objective delineation by k-means clustering for the use of DWI in cervical cancer, which may pave the way towards a more microstructurally informed radiotherapy dose planning.