Validation of a novel hybrid deformable image registration algorithm for cervix cancer

Buschmann M.¹,², Furtado H.¹,³, Georg D.¹,², Seppenwoolde Y.¹,²
¹Christian Doppler Laboratory for Medical Radiation Research for Radiation Oncology, Medical University of Vienna, Austria
²Department of Radiotherapy, Comprehensive Cancer Center, Medical University of Vienna / AKH Vienna, Austria
³Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Austria

Objective

Adaptive treatment approaches based on frequent imaging in the planning and/or treatment phase have been proposed for the external beam treatment of cervix cancer to account for large organ motion. To use the additional imaging data efficiently, deformable image registration (DIR) is needed for autocontouring, organ deformation and dose deformation. The hybrid DIR algorithm ANACONDA [1] (in PlayStation v5.0) that can deform images based on image intensity and contour information was validated for CT-to-CT-registration of the bladder, rectum and cervix-uterus (CTV-T).

Patients and Methods

CT datasets of 10 cervix cancer patients were used in this study. Each patient had one planning CT and 1-5 followup CTs in treatment. For each patient the planning CT was deformed to all following CTs together with the contours of bladder, rectum and CTV-T, resulting in a total of 25 registrations. DIR was performed in two ways: • based only on image intensity information (DIRimg) • based on image intensity and controlling structures delineated on both images (DIRstruct).

The performance of the DIR was validated by comparing delineated contours with deformed contours using geometric metrics (Dice coefficient=DSC, 95th percentile Hausdorff distance=HD). The overlap metrics resulting from rigid registration were used as baseline. A VMAT dose distribution (prescription: 45 Gy) was recalculated on the followup CTs and dose values (D2, Dmean and D98 for CTV) of the delineated and deformed organs were compared.

Results

The average DSC and HD values over all registrations are presented in Figure 2 together with the average improvement compared to rigid registration. The mean structure overlap was slightly improved with DIRimg (0.64) and strongly improved with DIRstruct (0.86) when compared to rigid registration (0.61). Minimum DSC was 0.36/0.04 for DIRimg/DIRstruct. Figure 3 displays the deviation in dose values from the reference contours. No systematic dose difference was observed for both DIR methods. Dose deviations were in general smaller for DIRstruct.

Conclusion

Large deformations occurring in the pelvis pose a challenge for DIR. The overlap of deformed and delineated organs is generally not satisfactory when using DIR based on image information only, therefore hindering autocontouring. Deformation based on controlling structures delivers improved results, which may make accurate dose accumulation for these organs feasible, if the images are manually contoured. Still, in extreme organ motion cases, also this approach led to poor results.

Fig. 1: DIR example in sagittal view: cervix-uterus (red), rectum (green), bladder (blue). Bright contour: ground truth. Dark contour: deformed structure. Left: image-intensily based DIRimg; Right: intensity and structure based DIRstruct.

Fig. 2: Geometric performance of the DIR algorithm. a) Average Dice coefficient (DSC) for rigid registration and the two DIR methods. b) average improvement in DSC over rigid registration. c) Average 95% Hausdorff distance (HD). d) average improvement in 95% HD over rigid registration.

Fig. 3: Average absolute difference in dose parameters between reference and deformed contours

Reference