Assessment of the generalizability to pediatric protontherapy of a 3D network generating pseudo-CT

Authors

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Purpose/Objective

A 3D convolutional neural network was used to map a Magnetic Resonance Imaging (MRI) into a pseudo Computed Tomography (pCT). It was trained and validated on an adults' cohort and tested on a cohort including protontherapy-treated pediatric patients only to evaluate the network robustness.

Material and Methods

The total cohort was composed of 341 brain tumor patients leading to 162 pairs of CT/T1 weighted MRI (T1) and 179 pairs of CT/contrast-enhanced T1 weighted MRI (T1-Gd) pairs. 242 (121 T1–121 T1-Gd) and 81 (41 T1–40 T1-Gd) adult patients were respectively used to train and validate a modified version of the 3D HighResNet (Li et al., 2017). Its main particularities were the residual connections and the dilated convolution filters, ensuring an absence of vanishing/exploding gradient effects and a high network receptive field respectively (Figure 1). Generalizability of the network was tested with 18 (18 T1-Gd) pediatric patients with a mean age of 12.5 years treated for a craniopharyngioma with a double scattering protontherapy. The CT plan was transferred to the pCT before recalculating the dose with the pencil beam algorithm implemented in ISOgray 4.2.1 (DOSIsoft).
Mean Absolute Error (MAE) within four areas (whole head, air, bone and water), global 1%/1mm, 2%/2mm and 3%/3mm gamma indexes and Dose Volume Histograms (DVH) differences corresponding to the planning target volume were computed to compare CT and pCT image intensities and dosimetric differences.

Results

The computation time for pCT generation was 83s on a single GPU GeForce GTX 1080Ti. Qualitative results are presented in Figure 2. Mean MAE of 111 Hounsfield Units (HU)+/-12HU, 364HU+/-56HU, 279HU+/-27HU and 60HU+/-10HU were obtained for the whole head, air, bone and water areas respectively. Regarding the dosimetry results, the 1%/1mm, 2%/2mm and 3%/3mm gamma indexes were equal to 96.44%+/-2.22%, 97.92%+/-1.54% and 99.59%+/-0.59% respectively. All 2%, 50%, 95% and 98% mean DVH differences were below 0.3%.

Conclusion

To our knowledge, it is the first study evaluating a 3D network with an unseen patient's category. In a previous study, a test with a cohort composed of 79 adults treated with intensity modulated radiation therapy led to a head MAE of 83HU+/-22HU, and gamma indexes of 97.90%+/-1.10%, 99.61%+/-0.30% and 99.83%+/-0.19% for the 1%/1mm, 2%/2mm and 3%/3mm criteria. As a result, very little differences were observed between the two studies highlighting the high generalizability of the developed model and its clinical implementation feasibility.

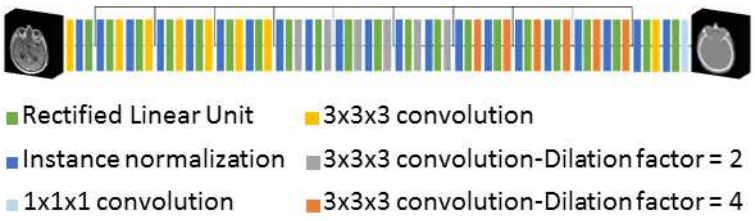

Fig. 1. Architecture of the modified HighResNet.

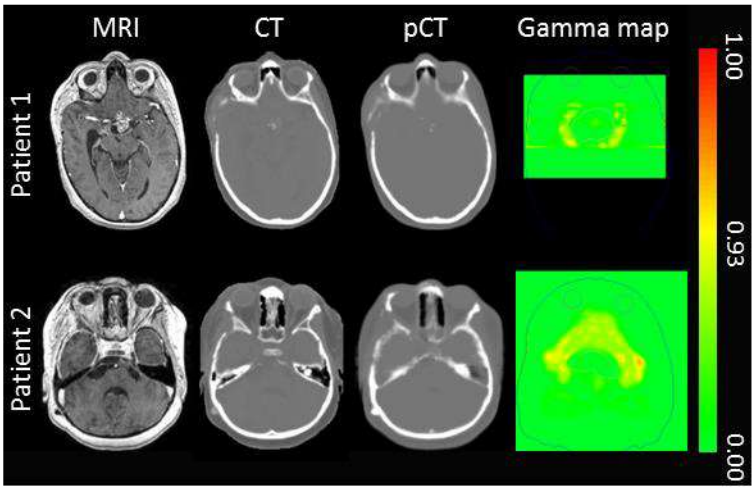

Fig. 2. T1-Gd MRI, CT, pCT and gamma map for the 3%/3mm criterion presented for Patient 1 (17 years old, 6 beams-based treatment) and Patient 2 (6 years old, 6 beams-based treatment). To improve visibility, outer and eyes contours are displayed on the gamma maps.