OC-0478 Neural network based synthetic CTs for adaptive proton therapy of lung cancer

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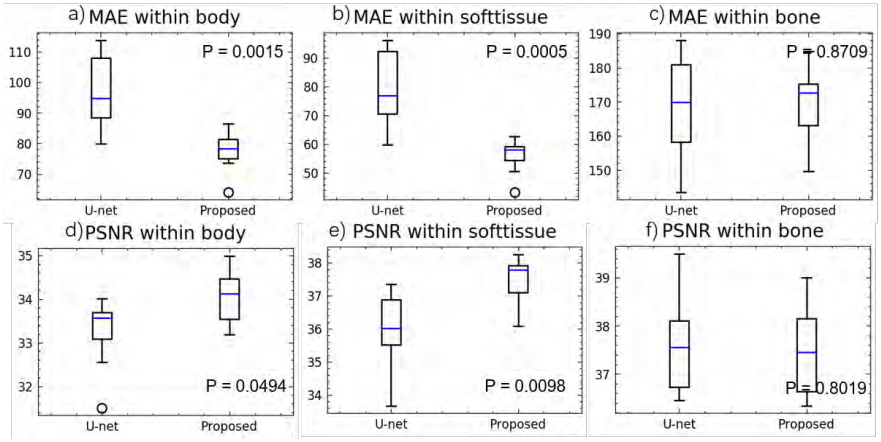

Figure 2. MAEs and pSNR calculated within the body, soft tissue, and bone with respect to the U-net and proposed model.

Conclusion

Qualitative and quantitative evaluation indicates that the proposed method can synthesize sCT with accurate CT numbers and best texture information, especially in soft tissue and the body. The achievement can increase treatment precision with sCT and show the potentiality in sCT-based organs contouring and dose calculation for adaptive radiotherapy.

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Purpose or Objective

Adaptive proton therapy (APT) accounts for anatomical and physiological changes to ensure target coverage and organ-at-risk sparing during the entire treatment course. An imaging modality that may detect these anatomical changes is cone-beam computed tomography (CBCT). However, CBCT-images suffer from severe image artifacts (e.g. scatter) that hinder accurate proton dose calculations. Deep convolutional neural networks (DCNN) have shown potential to correct CBCTs and create synthetic CTs (sCTs) that enable proton dose calculations in various anatomical locations (e.g head&neck, pelvis). In this study such a DCNN together with an accompanying planning CT (pCT) based patient specific correction technique was used to generate sCTs and their suitability for adaptive proton therapy of lung cancer patients was evaluated in terms of image quality and dosimetric accuracy.

Materials and Methods

A dataset consisting of CBCT- and same-day repeat CT-images from 33 lung cancer patients, treated with proton therapy, was used to train and evaluate the DCNN. 3-fold cross validation was employed to utilize all 33 patients for image and dosimetric evaluation. After the DCNN-conversion, an automatic patient specific correction method, using a smoothed and truncated difference map between the pCT and sCT, was introduced, mainly to correct CT-numbers of lung tissue, which are difficult to generate consistently and accurately by the DCNN.

For image quality assessment, mean absolute error (MAE) and mean error (ME) were calculated for sCTs with (sCT_{cor}) and without (sCT_{orig}) the pCT-based correction method. For the dosimetric evaluation, clinical treatment plans were recalculated on both synthetic CTs and gamma pass ratios (3%/3mm) were used to compare dose distributions to those calculated on the reference CT scans.

Results

Figure 1 shows an overview of CBCT, CT, sCT_{orig} and sCT_{cor} for patient 5 together with difference images between sCTs and CT. Average MAEs (ME) of 34.7±7.2 HU (5.2±9.8 HU) and 30.8±4.7 (2.7±4.8 HU) were observed for sCT_{orig} and sCT_{cor} respectively. The recalculation of clinical treatment plans resulted in average gamma pass ratios of 93.9±4.6 % for sCT_{orig} and 96.9±2.2 % for sCT_{cor}. Results from the gamma analysis are presented in Figure 2 for each patient individually.

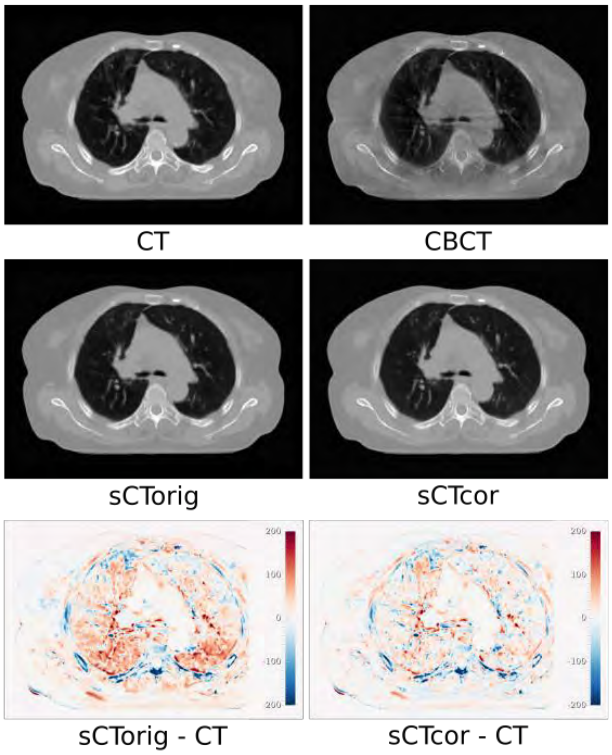

Figure1: Overview of reference CT, CBCT, original sCT (sCTorig), corrected sCT (sCTcor) together with difference images between sCTs and CT for patient 5 (worst case scenario). A HU window of [1700,-180] was used for all images.

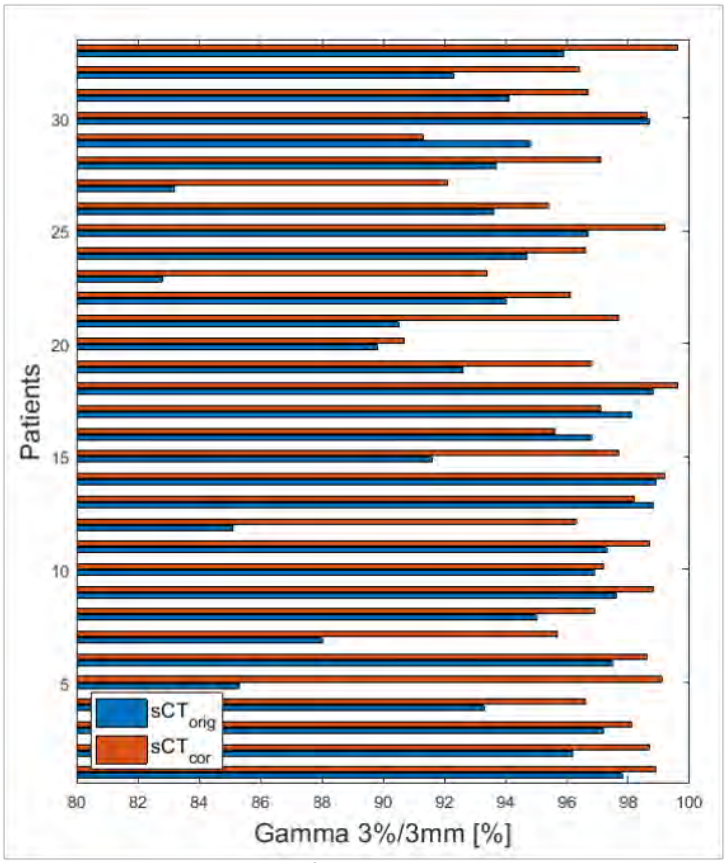

Figure 2: Comparison of 3%/3mm gamma pass ratios of sCT_{orig} and sCT_{cor} for each patient individually.

Conclusion
The image quality evaluation and the dosimetric accuracy assessment indicates that neural network based sCTs combined with a patient specific correction method may be utilized for adaptive proton therapy in lung cancer patients.

OC-0479 Towards CBCT-guided online adaptive radiotherapy for prostate cancer patients
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Purpose or Objective
Current challenges in radiotherapy include daily anatomical changes resulting in underdosage of the target and overdosage of the organs at risk (OARs). Online adaptive radiotherapy (oART) can in theory manage these inter-fractional variations. The aim of this study was to describe the first worldwide clinical implementation of CBCT-guided oART for prostate cancer patients, who were chosen as the first candidates because of inter-fractional variations in the pelvic region and the relative ease of anatomy.
Materials and Methods
Eleven prostate cancer patients were clinically treated with Ethos therapy (Varian Medical Systems, Palo Alto, CA) between February and July 2020, using a fractionation scheme of 20×3 Gy for the prostate and 20×2.7/3.0 Gy for the seminal vesicles for more advanced stages. Prior to the first adaptive fraction, influencers (prostate, seminal vesicles, rectum and bladder) and targets were manually contoured on the acquired planning CT. For each patient, a 9 field IMRT plan was created, applying a CTV-PTV margin of 7 mm in lateral and anterior-posterior direction and 8 mm in superior-inferior direction. During each adaptive session, a CBCT was acquired, on which the influencers were segmented by artificial intelligence and manually adjusted if necessary. After that, targets were propagated from the planning CT to the CBCT using a structure-guided deformation algorithm. The scheduled and adapted plans were recalculated and re-optimized on the CBCT anatomy, respectively. After an independent QA procedure (Mobius3D, Varian Medical Systems), the chosen treatment plan was delivered. The full team was present during the adaptive sessions, including two RTTs, a radiation oncologist, a medical physicist and a technical physician. Treatment time and fraction doses were compared.
Results
All patients completed treatment without any ≥ grade 2 CTCAE v5.0 toxicities. From CBCT acquisition to end of treatment delivery, the mean treatment time ± standard deviation was 17.4±1.9 minutes (range: 10.8-28.8 minutes). For all fractions, the adapted plan was preferred over the scheduled plan, because of increased target coverage (183/220 fractions) or a combination of increased target coverage and superior bladder and/or rectum sparing (37/220 fractions). In 14/220 fractions the increased target coverage of the adapted plan resulted in a violation of the V60Gy constraint of the bladder and/or rectum. Typical comparisons of scheduled and adapted plans are shown in Figure 1.

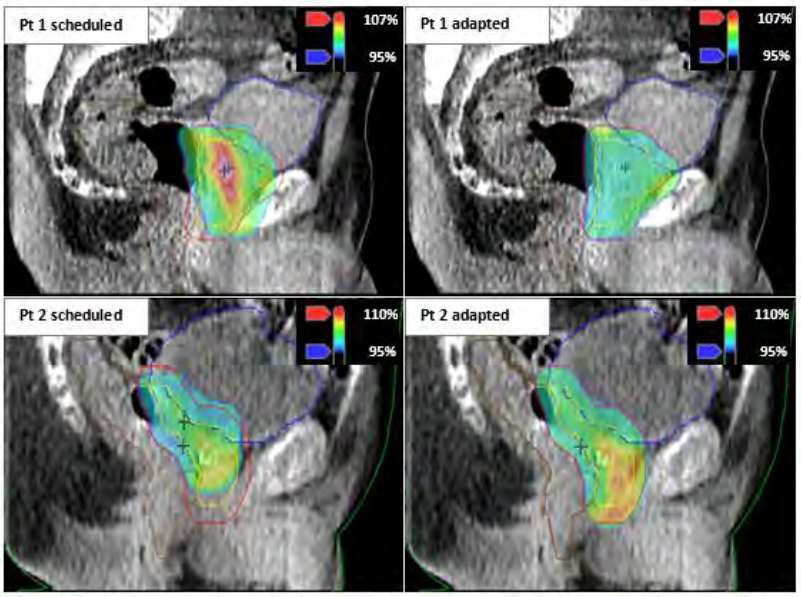

Figure 1: Two typical comparisons of isodose distributions in color wash of scheduled (left) and adapted plans (right). In patient 1 (above), the coverage of CTV (yellow) and PTV (red) increased, whereas bladder and rectum doses decreased for the adapted plan compared to the scheduled plan. In patient 2 (below), the increased coverage of CTV (yellow) and PTV (red) in the adapted plan resulted in a violation of the V60Gy<3% constraint of the rectum.

Conclusion
CBCT-guided oART for prostate cancer patients is feasible within twenty minutes with a dedicated team. Future steps include the implementation of an RTT-led workflow and oART for more indications in the pelvic region.

OC-0480 Range probing as a quality control tool for CBCT based synthetic CTs: an in vivo demonstration