Evaluation of CBCT-based synthetic CTs for clinical adoption in proton therapy of head & neck patients.

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PURPOSE

In adaptive proton therapy, weekly verification CTs (rCTs) are commonly acquired and used to monitor patient anatomy. Cone-Beam CTs (CBCT) on the other hand are used for daily pre-treatment position verification. These CBCT images however suffer from severe imaging artifacts preventing accurate proton dose calculations, meaning that CBCTs are unsuitable for treatment planning purposes. Recent advances in converting CBCT images to high quality synthetic CTs (sCTs) using Deep Convolution Neural Networks (DCNN) show that these sCTs can be suitable for proton dose calculations and therefore assist clinical adaptation decisions.

The aim of this study was to compare weekly high definition rCTs to same-day sCT images of head and neck cancer patients in order to verify dosimetric accuracy of DCNN generated CBCT-based sCTs.

MATERIALS & METHODS

For target volumes, the average difference in D_{98}% between rCT and sCT pairs (N=357) was 0.37±3.58 % [-0.20±1.91 Gy] for the low dose CTV (54.25 Gy) and -0.26±3.21 % [-0.18±2.19 Gy] for the high dose CTV (70 Gy). For the OARs the following mean dose differences were observed; Oral Cavity: 4.03±9.84 % [0.72±1.43 Gy], Parotid L: 5.84±13.37 % [0.60±1.46 Gy], Submandibular R: 2.10±8.44 % [0.53±2.57 Gy]. The average NTCP difference was -0.14±0.58 % for grade 3 dysphagia, -0.26±0.55 % for grade 3 xerostomia, -0.52±1.23 % for grade 2 dysphagia and -0.74±1.44 % for grade 2 xerostomia.

MATERIALS & METHODS

A dataset of 57 previously treated head and neck cancer patients was used to generate synthetic CTs from daily pre-treatment patient alignment CBCTs using a previously developed and trained U-net like DCNN. Proton dose was then recalculated on weekly rCTs and same-day sCTs utilizing clinical treatment plans. To assess the dosimetric accuracy of sCTs, dose to the clinical target volumes (CTV D_{98}) and mean dose in selected organs-at-risk (OAR; Oral cavity, Parotid gland left, Submandibular gland right) was calculated and compared between rCTs and same-day sCTs. Furthermore, Normal Tissue Complication Probability (NTCP) models for xerostomia and dysphagia were used to assess the clinical significance of dose differences.

CONCLUSION

For target coverage and NTCP difference, the deep learning based sCTs showed high agreement with weekly verification CTs. However, some outliers were observed (also indicated by the increased standard deviation) and warrant further investigation and improvements before clinical implementation. Furthermore, stringent quality control tools for synthetic CTs are required to allow reliable deployment in adaptive proton therapy workflows.

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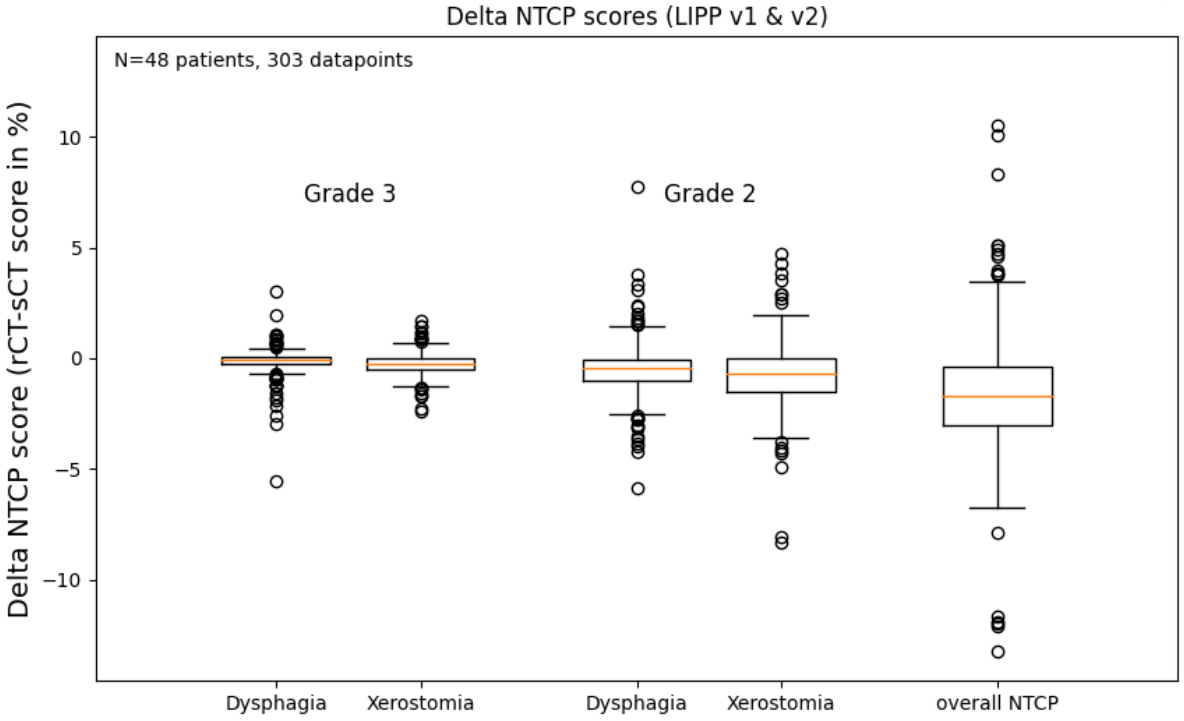

Figure 1: The mean delta NTCP score difference in percentage (%) between NTCP calculations on reference CTs and on same-day synthetic CTs. 10 patients were calculated with LIPP v1 and the remaining 38 with v2. The difference in version does not result in comparison problems for the NTCP scoring, as datapoints of the same version are compared.

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