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Evaluation of two adaptive radiotherapy workflows and their benefits for stage III non-small lung cancer with Cone-beam computed tomography-based synthetic computed tomography

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The goal of radiation therapy is to maximize the tumor control probability while minimizing the normal tissue complication probability. For stage III non-small cell lung cancer patients, the lungs, heart, and esophagus are the main limiting organs at risk (OAR), which are susceptible to pneumonitis, cardiovascular toxicity, and acute esophagitis due to high radiation doses. Modern concurrent chemoradiotherapy results in 5-year overall survival rates of 32-33%, which can be increased to approximately 43% with immunotherapy for eligible patients. Daily adaptive radiotherapy (ART) based on cone-beam computed tomography (CBCT) images, can further improve current radiotherapy by adapting the treatment plan to the potentially altered anatomy of the patient, especially to the possibly decreasing tumor volume. These treatment plan adaptations can either reduce the OAR dose without affecting the planning target volume (PTV) coverage, or increase the target dose without increasing the ipsilateral lung/OAR dose. However, CBCTs have an insufficient image quality due to severe artifacts and lack of a unique CT number-to-electron density assignment.
The aim of this thesis was to determine the dosimetric benefit of ART. The problem of insufficient CBCTs was addressed by generating synthetic CTs (sCTs) based on CBCTs using a cycle-generative adversarial network that was previously trained with datasets of 53 patients. Subsequently, the quality of the generated sCTs was assessed, the performance of a deformable image registration (DIR) algorithm on the sCTs was evaluated, and the benefit of daily ART for OAR sparing and target dose escalation was analyzed.
High quality sCTs for 15 independent evaluation patients were generated with this model with mean errors of 22.3HU±27.7HU. Mean dosimetric deviations of the analyzed DVH parameters for the target and OARs were less than 1.7% and 1.1%, respectively and median global 2D gamma pass rates (3%,3mm) were above 98.8%±1.6%. The image segmentation method using DIR achieved satisfactory results with mean Dice similarity coefficients above 0.82 for each structure, which were within the interobserver variability range, except for the heart.
After validating the dosimetric accuracy of the generated sCTs, it was shown that compared to the initial predicted dose without ART, the median $D_{95\%}$(PTV) decreased by 1.6Gy±4.2Gy, while the $V_{20Gy}(lung_{ipsilateral})$ increased by 1.1%±4.4%. The isoeffective scenario restored the PTV coverage and reduced the median $V_{20Gy}(lung_{ipsilateral})$ and $V_{5\%}$(heart) by 3.1%±3.6% and 2.9%±6.4%, respectively. The study also demonstrated the feasibility of dose escalation to the gross tumor volume of 10.0Gy±8.1Gy without increasing the $V_{20Gy}(lung_{ipsilateral})$ and V_{5Gy}(heart). Overall, the results showed that the generated sCTs are suitable for dosimetric calculations and that both ART scenarios provide dosimetric advantages.