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Auto-Contouring Electron Density Overrides during Stereotactic MR-Guided Online Adaptive Radiotherapy Treatment Planning of Pancreas Cancers

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Abstract

Objective: The purpose of this work was to develop an electron density (ED) override auto-contouring procedure to efficiently account for daily changes in patient gas while decreasing interobserver variability during abdominal MR-guided online adaptive radiotherapy (ART) treatments.

Methods: Ten previously treated MR-guided ART pancreas patients were selected to study the significance of ED overrides on the Monte Carlo-based dose calculation within the MR-Linac's commercial treatment planning system. Patient plans were initially developed during the online adaptive workflow to deliver an SBRT course of 50 Gy in five fractions via an MR-Linac system that combines a 0.345 T magnet with a 6 MV flattening filter free beam. Treatment plans consisted of 18-24 step-and-shoot IMRT beams distributed evenly around the patient, except through the arms. Within this study, manually-contoured ED overrides were replaced with auto-contoured ED overrides using a range of auto-contouring parameters. Prescription dose volume histogram (DVH) metrics, including the volume of gastrointestinal organs at risk (GI-OARs) receiving 33 Gy (V33Gy) and the dose covering 95% of the target volume (D95%), were evaluated for the treated plans calculated on ED maps with auto-contoured overrides and with no ED overrides and compared to the metrics from the original calculations. The distributions of the differences in the DVH metrics amongst the 60 unique clinical treatment plans (one base plan and five online ART plans per patient) were studied to identify the optimal auto-contouring parameters and the feasibility of replacing the manually-contoured ED overrides in our clinical workflow. Student's t-test was used to assess differences between auto-contoured overrides and manual overrides, with p-values below 0.05 considered statistically significant.

Results: Two representative patients (12 evaluated treatment plans) were chosen to study the sensitivity of the dose calculation to auto-contouring parameters, including image values and contour smoothing. The mean and standard deviation of the magnitude of the differences in the duodenum, stomach, colon, and small bowel V33Gy values were minimized when MRI air included image values 0 to 35, CT air included image values -1024 to -200, and a smoothing kernel of 0.3 cm was used to clean the contours. When applying the optimal auto-contouring parameters to the entire data set, the mean and standard deviation of the magnitude of the differences in the duodenum, stomach, colon, and small bowel V33Gy values were: 0.037 ± 0.070, 0.024 ± 0.050, 0.020 ± 0.044, and 0.021 ± 0.038 cm3. The mean and standard deviation of the magnitude of the differences in the clinical target volume D95% values were: 0.258 ± 0.483 Gy. Only the difference in small bowel volumes was found to be statistically significant. When ED overrides were not used in the dose calculation, three out of 60 treatment plans exceeded at least one of the prescribed GI-OAR dose constraints. The tested auto-contouring procedure was developed and validated on pancreas ART treatment plans and is therefore only suitable for gastrointestinal gas pockets found in abdominal treatment sites.

Conclusion: The chosen ED auto-contouring thresholds yielded dose calculations with prescription DVH metrics that were similar to those in the treated plans with manually-contoured EDs. Utilizing auto-contoured overrides is an improvement over eliminating override use, when patient GI-OAR anatomy is notably dynamic. The auto-contouring procedure decreases the patient's time on the treatment table during adaptive SBRT treatments, irrespective of the volume of gas, and removes interobserver variability in contouring.