Plan Quality Assessment for Rectal Cancer Patients Using Prediction of Organ-At-Risk Dose Metrics

Ana Vaniqui, Richard Canters, Femke Vaassen, Colien Hazelaar, Indra Lubken, Kirsten Kremer, Cecile Wolfs, Wouter van Elmpt

Maastro Clinic, Maastricht, The Netherlands

Introduction

With the introduction of automatic planning, assessment of plan quality of individual plans becomes more difficult. We developed an automatic anatomy-based plan quality method that predicts the organ-at-risk (OAR) dose. This method was applied to rectal cancer patients and compared patient cohorts of automatically generated treatment plans with manual treatment planning.

Methods

A total of 196 stage I-III rectal adenocarcinoma patients treated according to institutional guidelines with a VMAT protocol (25x2Gy) were included in this study. A dose prediction model based on the overlap-volume histogram (OVH) concept (Petit and van Elmpt, R&O-2015) was trained on a cohort of 22 patients. From this cohort, the mean dose relative to the distance from the planning target volume (PTV) to the two relevant OARs (bowel bag and bladder) was calculated. From this dose-distance curve, DVH prediction parameters for the selected OAR were derived solely based on the anatomical position of the PTV and OAR. Figure 1 shows the rationale of the model. This model was subsequently evaluated on two validation cohorts: 1) 93 patients treated using a manually optimized treatment plan and 2) 95 automatically planned patients (RapidPlan™, Varian Medical Systems). OAR dose differences for the PTV coverage, bowel bag, and bladder were compared to the predicted dose levels from the model.
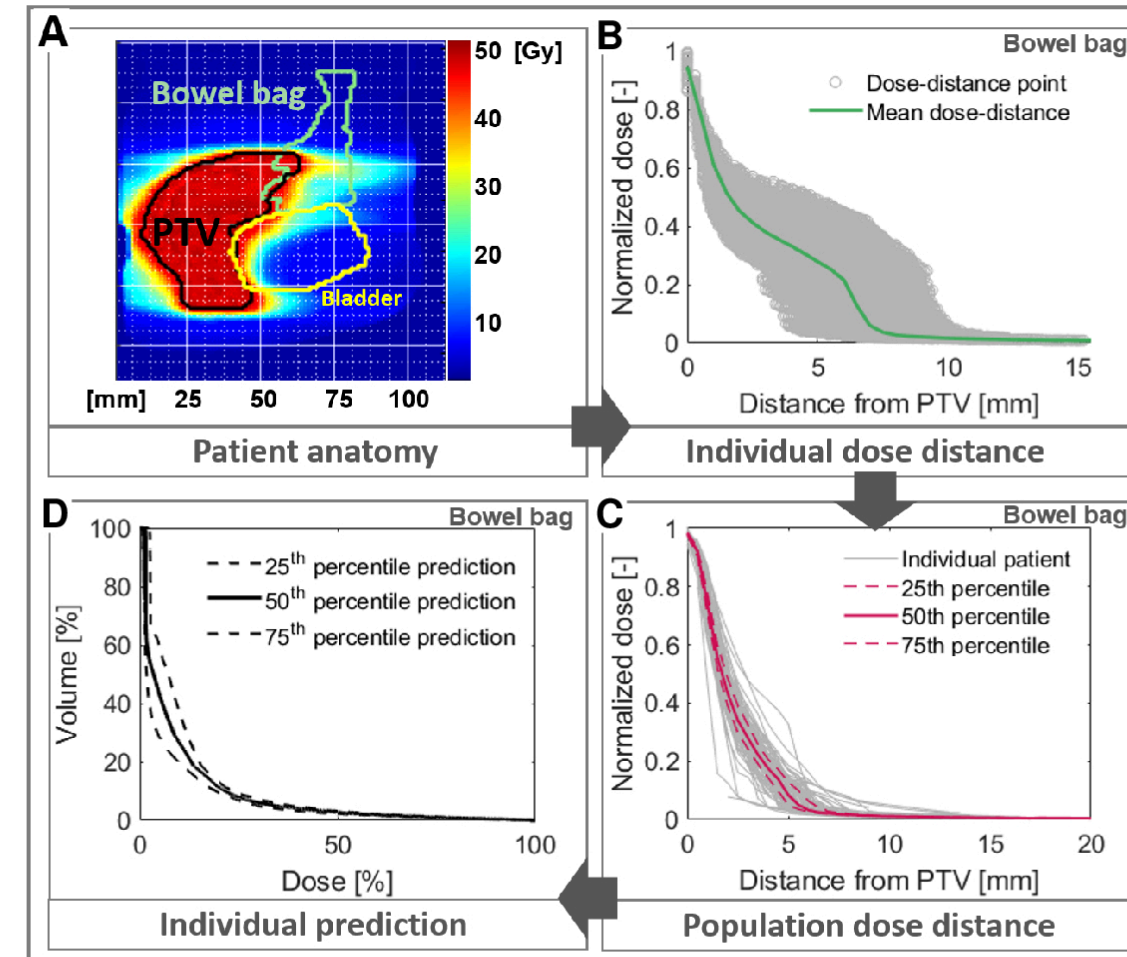

Figure 1: Prediction model schematic summary. A) patient anatomy: a dose-distance point is a dose point at a distance from the PTV. B) individual patient's OAR specific dose-distance points and mean dose-distance relation. C) every patients' mean dose-distance and the population's 25th, 50th, and 75th percentile dose-distances curves. D) 25th, 50th, and 75th percentile DVH prediction curves for a new patient based on the population curve. They are achieved by calculating the inverse cumulative histogram of the doses in the calculation points. The dose to each calculation point is determined by the dose corresponding to the same distance from the population curve, considering the anatomy of the new patient. DVH prediction based on these population curves correspond to the training cohort best 25%, 50%, and 75% plans
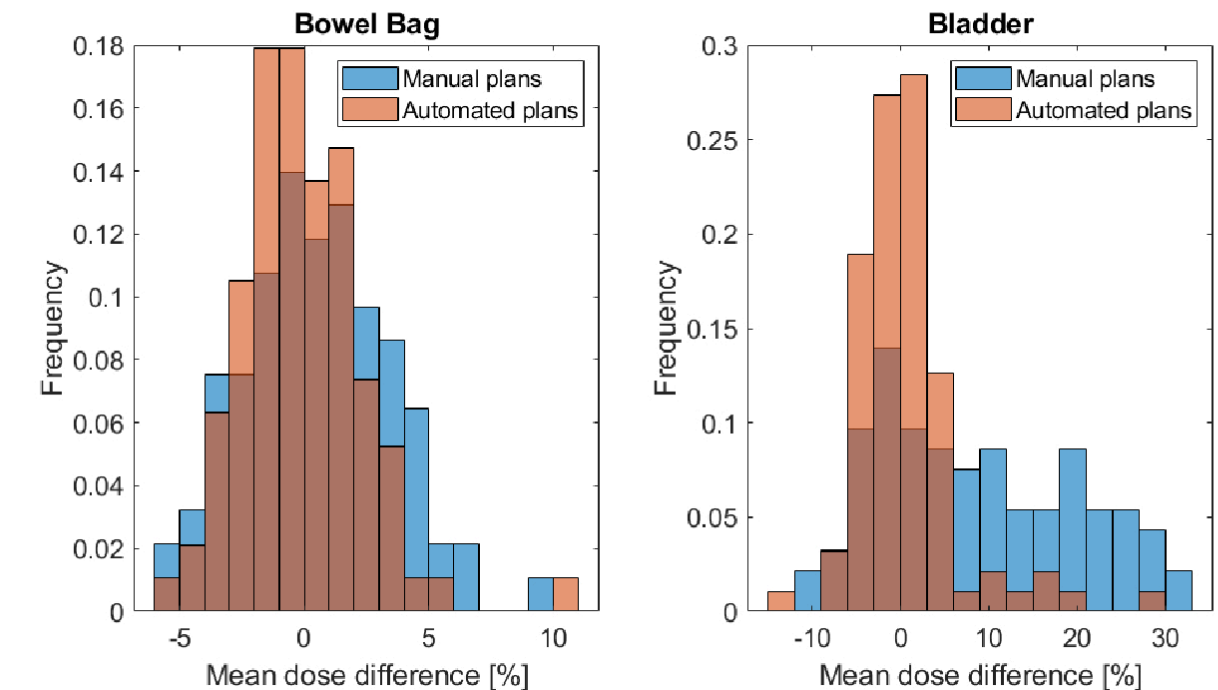

Figure 2: Difference between predicted and achieved mean dose to the bowel bag and bladder for individual patients normalized to the mean PTV dose. Comparison between manual (blue) and RapidPlan™ (red) plans for the bowel bag (left) and the bladder (right). The predictions are derived from the median population dose–distances in the 22 patients training cohort.

Results

Figure 2 shows the comparison between achieved and predicted mean doses for the 3 cohorts and 2 OARs investigated. For the clinical standard cohort, prediction accuracy of 0.3±1.4 Gy and -0.3±8.9 Gy was found for the mean doses to the bowel bag and bladder, respectively; for the automated a lower standard deviation was observed: 0.5±2.9 Gy and -0.4±0.6 Gy, respectively. The interquartile range of DVH parameters was on average smaller for the automated cohort, indicating a lower variation within each parameter.

Conclusion

An independent patient-specific plan QA method for rectal cancer patients was validated in two clinical cohorts. Dose values were accurately predicted for both OARs. Manual treatment planning showed larger variation and sub-optimal plan quality compared to RapidPlan™ generated treatment plans. This QA method can be used clinically to flag outliers in plan quality.

Ana Vaniqui
ana.vaniqui@maastro.nl

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