End-to-end automatic treatment planning for prostate radiotherapy

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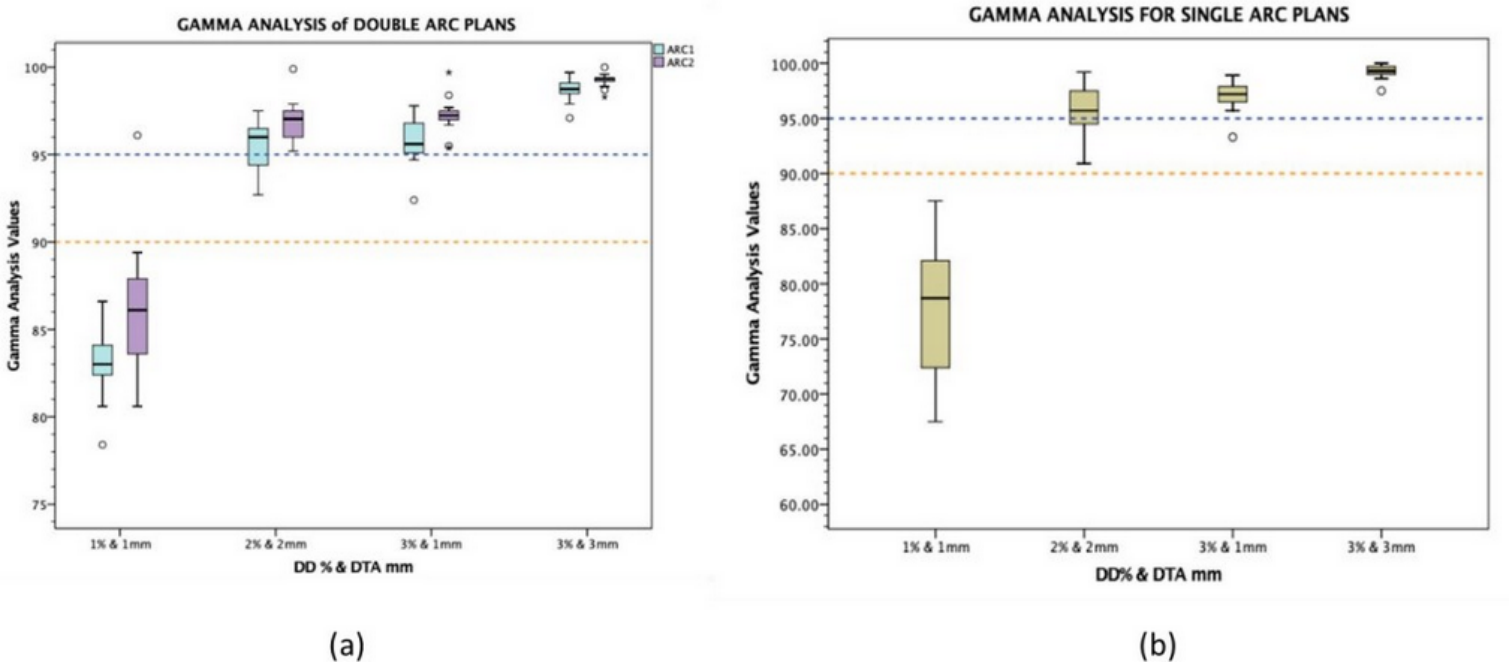
Purpose/Objective:
Automation of radiotherapy treatment planning is a highly investigated topic today. Promising results have been reported regarding the breakdown of the automated planning (AP) pipeline into knowledge-based dose prediction followed by dose mimicking [1,2]. The ultimate goal of AP is efficient generation of high-quality plans that do not depend on human time and experience. In this study we propose an end-to-end pipeline for normo-fractionated prostate cancer treatments that requires minimal human input and generated machine-deliverable volumetric modulated arc therapy (VMAT) plan as output.

Material/Methods:
We retrospectively collected 123 intact prostate cases from a renowned European cancer center, following a prescription of 80 Gy to the prostate and simultaneously 56 Gy to the seminal vesicles in 40 fractions, as per clinical protocol [3].
A U-Net-style deep learning model was trained on 92 cases and a held-out set of 31 cases used for model validation. VMAT plans were obtained by performing a direct aperture optimization using custom implementation of two types of gradient-based optimization algorithms. The optimization task employed loss function that penalized, for each anatomical or planning structure, deviations from the voxelwise doses predicted by the deep learning model. Objectives weights were selected via hyperparameter tuning.
For each automatically generated plan, final dose calculations were performed on the Eclipse treatment planning system (TPS) using AAA dose calculation algorithm and doses were normalized following the reference center practices (D50 to the prostate PTV set to 100% of the prescribed dose). Plan deliverability as assessed via portal dosimetry on TrueBeam linac (global gamma index 1%/1mm, 2%/2mm, 3%/1mm and 3%/3mm, 10% threshold).

Additionally, the reference clinical manual plans were compared with the automated plans in terms of monitor units (MU) numbers, modulation complexity scores (MCS) and dose differences. Subsequently the deliverability of the plans was assessed on another combination of TPS vendor and linac machine (data not shown).

Results:

Overall the results show that the plans achieved with the AP pipeline show successful deliverability and passed the porta dose dosimetry verification with gamma index values over 95% of all the gamma criteria except the 1%/1mm (Figure 1) which was expected.
Despite higher mean total MUs (MP=600 [484-772] vs AP=648 [514-806]), we observed lower MCS (MP=0.20 [0.12-0.26] vs AP=0.16 [0.12-0.22]) and the plans were dosimetrically acceptable and often superior to manual plans with respect to clinical dose constraints (Figure 2a and 2b). Moreover, for each arc, no statistically significant correlations were observed between any of the gamma criteria tested and the number of MUs or MCS. Similarly, the results were successfully validated on another TPS vendor and linac (data not shown)



(a) (b)

Figure 1. Gamma analysis results for double arc plans (a) and for single arc plans (b). The blue dashed line marks the threshold for passing the test; yellow dashed line marks the threshold for clinical acceptable results.

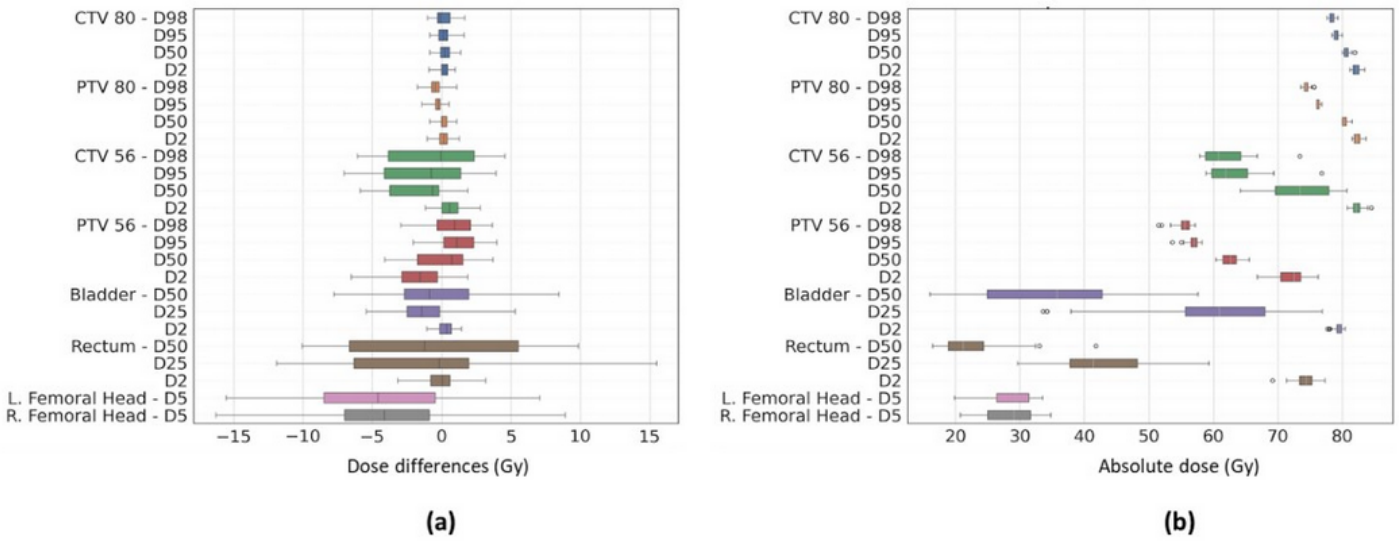


Figure 2. Dosimetric study results (a) differences between automated plans and reference manual plans and (b) absolute dose values for automated plans.

Conclusion:

This study shows the feasibility of a fully automated treatment planning pipeline that generated deliverable high quality plans that are competitive with manually made, clinically approved in terms of dosimetry and machine deliverability. Following this approach, a clinical workflow could consist of simply submitting a planning CT, approved OAR and PTV contours, a prescription, and choice of Linac to our automatic planning pipeline. In the future, this framework will be extended to other prescriptions and anatomical regions.

Keywords: auto-planning, prostate cancer, dose mimicking

References:

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