AI-Driven Patient-Specific Framework for Dose Prediction and Toxicity Estimation to Support Value-Optimized Treatment Strategy Planning in Prostate Radiotherapy

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BACKGROUND

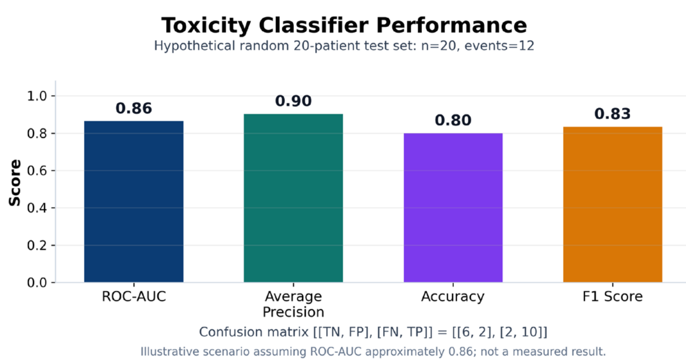
- Selecting an optimal radiotherapy strategy requires balancing tumor control, normal tissue toxicity, patient-specific factors, and healthcare value.
- Current workflows evaluate only a small number of candidate plans because each requires time-intensive treatment planning.
- AI-based dose prediction enables rapid comparison of multiple candidate treatment strategies before clinical plan generation.
- LLMs can integrate AI predictions into transparent, physician-readable decision-support summaries that facilitate treatment strategy planning.

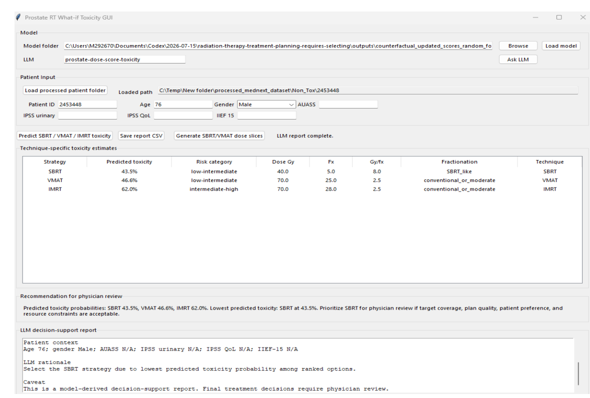
OBJECTIVES

- Develop an AI-assisted pre-planning framework for treatment strategy evaluation.
- Predict 3D dose distributions for candidate treatment strategies.
- Estimate patient-specific treatment toxicity risk.
- Support physician decision-making before treatment plan optimization.

RESULTS

- **Dose Prediction**
  - Held-out dose prediction achieved a mean MAE of **0.83 Gy** (3.86 Gy in high-dose regions).
  - Median full-cohort QA demonstrated body MAE of **1.21 Gy**.
- **Toxicity Prediction**
  - Held-out testing achieved **ROC-AUC 0.86**, **AP 0.90**, **accuracy 0.80**, **and F1 score 0.83**.
  - The classifier correctly identified 16 of 20 held-out patients.
  - Confusion matrix [[TN, FP], [FN, TP]] = [[6, 2], [2, 10]].
- **Framework Demonstration**
  - Proof-of-concept strategy comparisons generated patient-specific dose predictions, toxicity estimates, and physician-readable treatment strategy summaries.

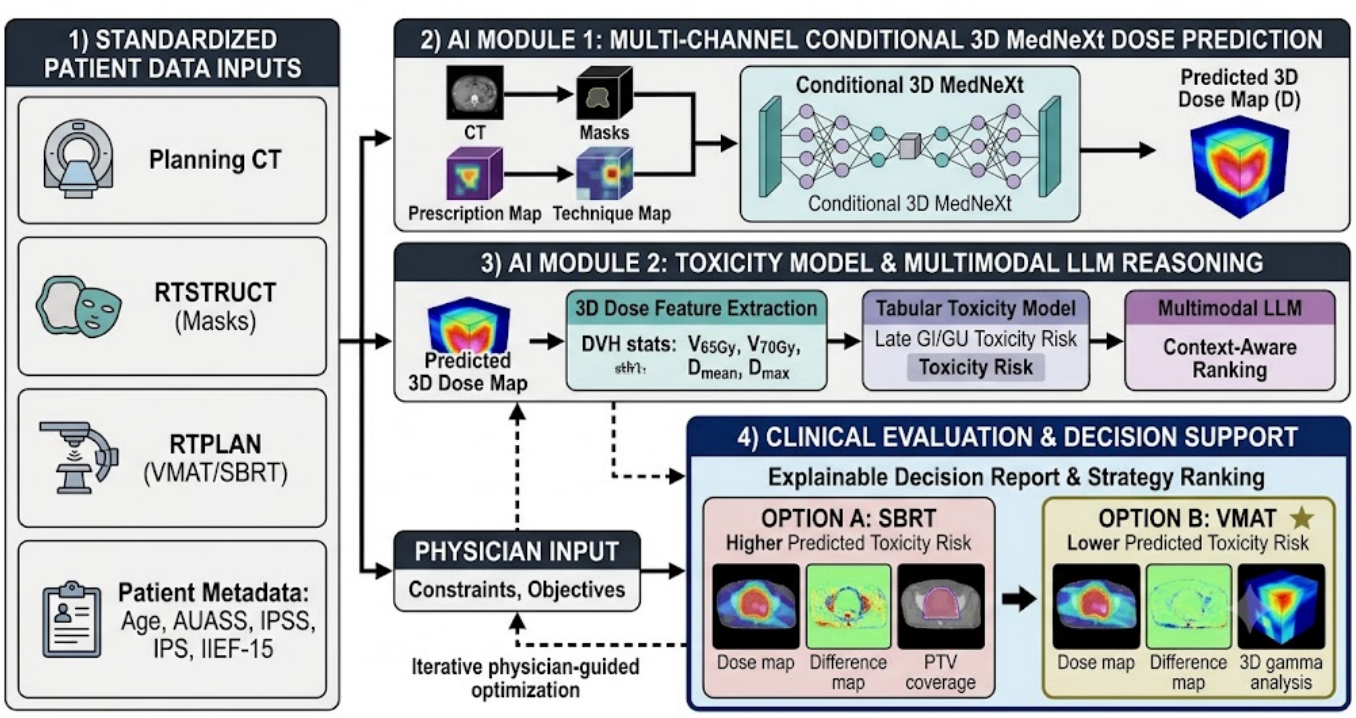




METHODS

- **Cohort:** 100 prostate RT patients (50 toxicity / 50 non-toxicity)
- **Inputs:** Planning CT, RT structures, RT dose, prescription, treatment technique, AUASS, and IPSS
- **Dose prediction:** Conditional 3D MedNeXt predicts patient-specific dose distributions
- **Toxicity estimation:** Dosimetric and clinical features predict late GU/GI toxicity risk
- **Decision support:** LLM generates physician-readable comparisons of candidate treatment strategies

FIGURE 1: AN INTEGRATED AI FRAMEWORK FOR PERSONALIZED PROSTATE RADIATION TREATMENT SELECTION



DISCUSSION

- Proof-of-concept for an integrated AI framework for pre-planning treatment strategy evaluation.
- Future work will expand validation across larger datasets and additional disease sites.
- The scalable framework can integrate new predictive models, clinical data, and treatment modalities.
- Long-term goal: personalized, value-optimized treatment strategy planning in radiation oncology.

CONCLUSION

- We developed an integrated AI framework that enables pre-planning evaluation of competing radiotherapy strategies using dose prediction and toxicity estimation.
- This scalable platform has the potential to transform value-optimized and personalized treatment strategy planning and clinical decision support in radiation oncology.

REFERENCE

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