Theme: Physics

Abstract No: PTCOG-AO2025-ABS-0095

Abstract Title: Accelerating Robust Proton Therapy: A Synthetic CT-Based Framework for Efficient and Clinically Feasible Adaptive IMPT

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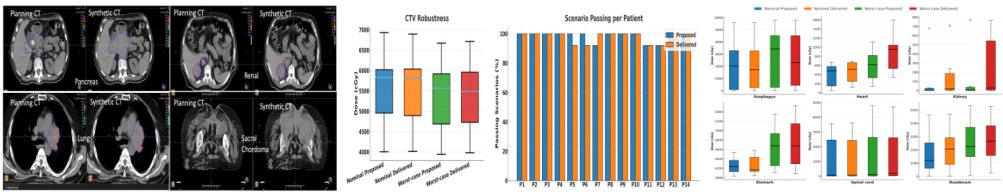
Background / Aims:

•To develop a two-scenario robust optimization model using planning CT and synthetic CT generated with voxel-specific worst-case water-equivalent path length (WEPL), and
•To benchmark its robustness, clinical feasibility, and computational efficiency relative to conventional multi-scenario robust optimization.

Subjects and Methods:

Synthetic CT Generation:
Voxel-specific HU modifications were derived from beam-specific WEPL perturbations to model setup and range uncertainties, creating a synthetic CT.
Robust Optimization: Robust IMPT optimization was performed in *RayStation v12* using only *two scenarios* (planning CT and synthetic CT), replacing the conventional 21-scenario approach.
Evaluation: Tested on *14 clinical cases* (lung, sacral chordoma, gastrointestinal). Original beam setups and objectives were retained. *CTV V95% ≥ 95%* and OAR doses were compared between proposed and clinically delivered plans.

Result:



Robustness and Dosimetric Performance:
Synthetic CT–based plans consistently achieved *CTV V95% ≥ 95%*, with improved robustness in three borderline cases. Worst-case doses to major OARs (*lungs, heart, stomach, duodenum, kidneys*) were reduced, indicating safer dose margins and better compliance with institutional constraints.
Computational Efficiency:
The framework reduced optimization time by over *75%* e.g., *3364 cc sacral chordoma* completed *150 iterations in 17.1 min* (vs >70 min conventionally), and smaller tumors finished in *<5 min*, confirming suitability for real-time adaptive workflows

Conclusion:

The synthetic CT–based robust optimization framework enables fast, clinically robust IMPT planning with maintained target coverage and OAR sparing, potentially offering a practical solution for real-time adaptive proton therapy.