2026 JOINT AAPM | COMP MEETING
JULY 19–22 | VANCOUVER, BC

Multi-Target Treatment Planning and Delivery on a PET-Linac Platform: Dosimetric Robustness and Efficiency in Oligometastatic Radiotherapy

Min Geon Choi[a], Girish Bal[c], Andrew Godley[a,b], Thomas I. Banks[a], Chenyang Shen[a,b], Rameshar Prasad[a,b], Shahed Badiyan[a], Steve Jiang[a,b], Robert Timmerman[a], Bin Cai[d,*]

[a] UTSW medical center, [b] Medical Artificial Intelligence and Automation Laboratory UTSW, [c] RefleXion Medical, [d] Mayo Clinic

2026 JOINT AAPM | COMP MEETING
JULY 19–22 | VANCOUVER, BC

Abstract

. Background: Treating multiple oligometastatic lesions via stereotactic body radiation therapy (SBRT) typically requires multiple separate treatment plans, resulting in increased planning complexity and longer delivery times. In this work, we evaluate a multi-target treatment (MTT) approach that integrates biology-guided radiotherapy (BgRT) for FDG-avid lesions with image-guided radiotherapy (IGRT) for non-PET-avid lesions in a single treatment plan, delivered on a PET-linear accelerator.

. Methods: Two representative clinical cases (one lung and one pelvis) were planned and delivered using MTT as well as a separated BgRT+IGRT approach. Plan quality was evaluated by considering the conformity index (CI), homogeneity index (HI), PTV coverage, and organ at risk (OAR) sparing. Dose volume histograms (DVHs) were reviewed for inter-target dose overlap, and the total beam-on time was recorded.

. Results: MTT achieved comparable or superior dosimetric outcomes while reducing total delivery time by 20–30%. For Case 1 (dual lung lesions in different lobes), MTT improved BgRT target conformity CI (1.26 vs. 1.37) and reduced treatment time by 25%. In Case 2 (adjacent pelvic bone lesions), separate BgRT+IGRT plans resulted in overdose in the IGRT target due to dose overlap from the BgRT target. The corresponding MTT plan did not suffer from this problem due to its simultaneous optimization of the BgRT and IGRT treatments, which helped to maintain a uniform dose distribution and reduce total treatment time by 22%.

. Conclusion: This work indicates that MTT plans are dosimetrically advantageous and clinically efficient. MTT simplifies multi-lesion SBRT planning, minimizes unwanted dose overlap between targets, and reduces overall treatment time without compromising dosimetric quality.

Introduction

- The RefleXion X1 system is an innovative Biology-guided radiotherapy (BgRT) system that uses the real-time PET signals from the tumor to direct the external beam radiation to the target.
- Biology guided radiation therapy (BgRT) employs positron emission tomography (PET) signals from the tumor to precisely guide external beam radiation to the target.
- Consequently, patients with oligometastatic cancer often require concurrent IGRT and BgRT, a dual technique, that
- Treatment (MTT) technique, that jointly optimizes BgRT and SBRT in a single treatment plan thereby enabling the simultaneous treatment of multiple targets to enhance the treatment efficiency and patient convenience.

Materials and Method

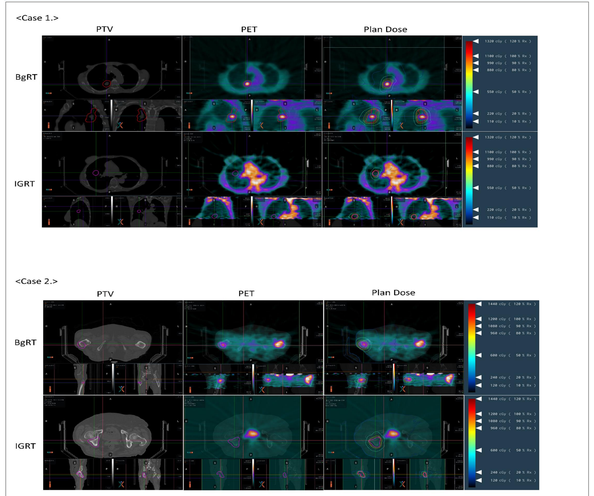

Fig 1. Transaxial views showing PTV contours, PET signal overlay, and dose distribution for a unified MTT plan in a dual-lung-lesion case. The PET-avid RUL lesion is treated with BgRT and the anatomically defined RLL lesion with IGRT

2.1 PET-Linac Platform & SCINTIX Criteria:

. Hardware: RefleXion X1 system combining a 6 MV FFF linac, fast-rotating ring gantry (60 RPM), 100 Hz binary MLC, kVCT, and dual 90° orthogonal PET arcs.

. SCINTIX biological limits for BgRT: Target size cm; metabolic contrast ; activity concentration (AC) kBq/mL; Normalized Target Signal (NTS) for planning and for delivery; separation cm from adjacent avid organs.

2.2 Unified MTT Planning and Delivery:

. Optimization: Combines 1 BgRT target and up to 10 IGRT targets in a single treatment file. Resolves direct and cross-dose (inter-target) contributions concurrently using a multi-objective optimization algorithm.

. Delivery Sequence: Patient setup single kVCT scan PET pre-scan evaluation BgRT delivery **automated couch shift** localized kVCT IGRT delivery in one single session.

2.3 Clinical Cohort & Validation:

. Case 1 (Lung): RUL (BgRT, 5500 cGy/5 fx) and RLL (IGRT, 5500 cGy/5 fx) geographically separate.

. Case 2 (Pelvis): R Femur (BgRT, 1200 cGy/1 fx) and R Acetabulum (IGRT, 1200 cGy/1 fx) - closely spaced target geometry.

Results

. Case 1 Lung Case: MTT maintained excellent target coverage (RUL PTV: 94.1%, RLL PTV: 96.5%) comparable to separate SBRT plans (94.2% and 99.6%). Crucially, MTT **improved RUL target conformity (CI: 1.26 vs. 1.37)** while reducing the peak dose hotspot (Dmax: 7578.5 vs. 7790.3 cGy). Critical OARs (spinal cord, heart) saw substantial dose reductions (spinal cord Dmax reduced from 26.46 to 22.05 cGy).

. Case 2 Adjacent Pelvis Case: In separate planning, summing independent doses revealed a cumulative hotspot inside the Acetabulum target of **1506.5 cGy (25.5% over prescription!)**. MTT's simultaneous optimization successfully constrained this to 1389.9 cGy, representing an **8.4% absolute hot-spot reduction**, while fully preserving target coverage (93.5%).

Discussion

. Cross-Dose Mitigation: Summing separate plans in Case 2 showed a dangerous cumulative hotspot inside the Acetabulum target (cGy; 25.5% overdose). MTT unified optimization successfully resolved this by globally optimizing fluence profiles, limiting peak dose to cGy (an 8.4% absolute hotspot reduction) without sacrificing coverage.

. Workflow Efficiency: Treating multiple lesions within a single patient setup and execution cycle on the RefleXion system saved **22% to 25%** of patient-on-table time (approx. 10–15 mins per session). It eliminates redundant kVCT alignment checks, couch shifts, and iterative planning cycles.

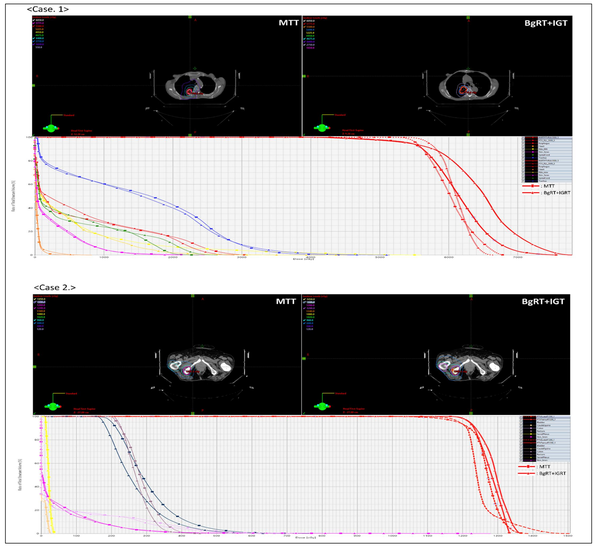

Figure 2. Comparison of DVH and dose distributions for unified MTT versus separate BgRT+IGRT planning, showing improved control of high-dose spill and maintained target coverage within clinically acceptable limits.

Conclusion

. The MTT framework represents a clinically feasible, dosimetrically robust, and highly efficient solution for multi-lesion SBRT. MTT simplifies multi-lesion SBRT planning, minimizes unwanted dose overlap, and reduces overall treatment time without compromising dosimetric quality.

Contact

Name: Min Geon Choi
Organization: Department of Radiation Oncology, UTSW
Email: mingeon.choi@utsouthwestern.edu

References

1. Rogowski, P.; Trapp, C.; Von Bestenbostel, R.; Schmidt-Hegemann, N.-S.; Shi, R.; Ilhan, H.; Kretschmer, A.; Stief, C.; Ganswindt, U.; Belka, C.; et al. Outcomes of Metastasis-Directed Therapy of Bone Oligometastatic Prostate Cancer. *Radiat Oncol* **2021**, *16*, 125, doi:10.1186/s13014-021-01849-8.
2. Norihisa, Y.; Nagata, Y.; Takayama, K.; Matsuo, Y.; Sakamoto, T.; Sakamoto, M.; Mizowaki, T.; Yano, S.; Hiraoka, M. Stereotactic Body Radiotherapy for Oligometastatic Lung Tumors. *International Journal of Radiation Oncology*Biology*Physics* **2008**, *72*, 398–403, doi:10.1016/j.ijrobp.2008.01.002.