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Feasibility of VMAT-Based Total Body Irradiation Using High-Resolution Multileaf Collimators: A Multi-Isocenter Strategy

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Abstract

TBI is a whole-body conditioning technique increasingly delivered with VMAT, which has traditionally required a large-field MLC. Many clinics have only high-definition (HD) MLCs with smaller fields. This work compares HD-MLC and Millennium VMAT TBI and identifies the planning geometry HD-MLC delivery requires.

Property	Millennium	HDMLC
Leaf width	40x0.5 cm inner	32x0.25 cm inner
	20x1.0 cm outer	28x0.5 cm outer
Max MLC-defined field size	40Y x 40X	22Y x 32X
Leaf thickness	6.7 cm	6.9 cm
density (g/cm3)	17.15-17.85	18.0-18.53

Table 1: Properties of each MLC system

Introduction

- TBI conditions patients before bone-marrow transplant (1).
- Conventional 3D TBI gives non-uniform dose and high organ-at-risk (OAR) dose (2–7).
- Helical tomotherapy and VMAT improved TBI dosimetry (8–12).
- VMAT TBI usually needs a large-field MLC (Millennium); HD-MLCs are common but have a smaller field.
- Goal: compare HD-MLC vs Millennium and recommend an HD-MLC planning approach (MLC specs in **Table 1**).

Methods and Materials

- 10 prior VMAT TBI patients, re-planned in Eclipse v18 with both HD-MLC and Millennium MLC.
- 6 MV; 200 cGy × 1 fraction. 300cGy/min max dose rate for thorax isocenters
- Three techniques — Conventional, HD-Single, HD-Dual (**Table 2**; geometry in **Figure 1**).
- Optimization: mean lung dose < 75% Rx; other OARs ≤ maximum Rx.
- Compared D80 / D50 / D10 for PTV and OARs (bowel, heart, kidneys, lungs, liver).
- Homogeneity index used to compare plans: $\left(\frac{D_2-D_{98}}{D_P}\right)$, D_x x% of prescription dose

Technique	Description
Conventional	Standard geometry using 4–5 midline isocenters and a multileaf collimator (MLC) with a 40 × 40 cm maximum field size.
HD-Single	Same isocenter configuration as the conventional technique, using a high-resolution MLC with a reduced field size of 22 × 32 cm.
HD-Dual	Modified geometry with laterally split isocenters (±10 cm from midline) to accommodate the limited field size of the HD-MLC, while preserving midline isocenters for setup reproducibility.

Table 2: Planning Parameters for each TBI plan

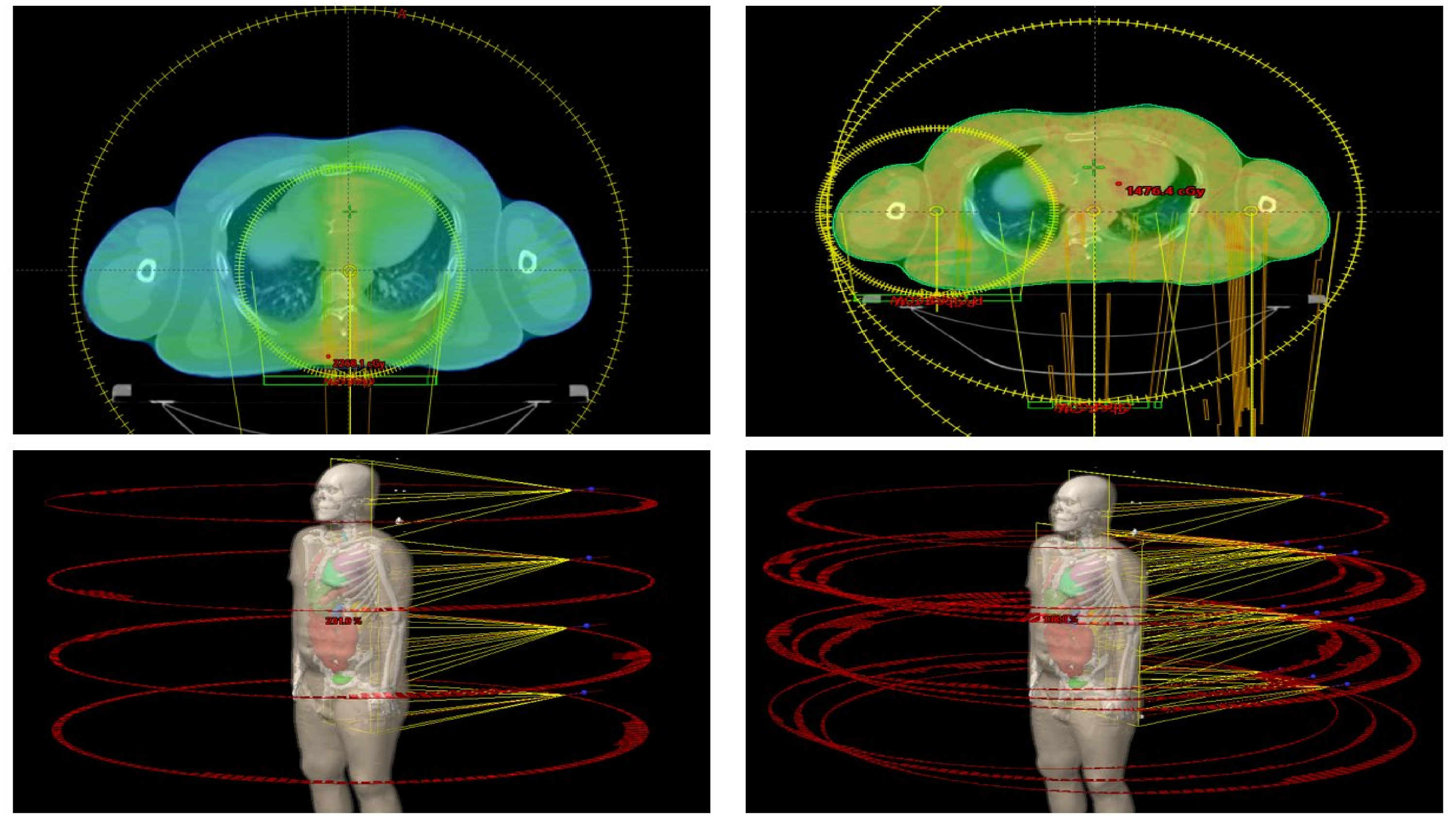


Figure 1. 3D display of beam design using Conventional MLCs (left) and High definition MLCs (right) with dual isocenters split)

Results

- **Figure 2** compares D50 for HD-Dual vs Conventional across target and OARs.
- HD-Dual ≈ conventional for coverage and conformality (PTV D50 105.8% vs. 108.6%, p = 0.37).
- Only the lungs differ significantly: D50 56.1% → 67.0% (+10.8%, p = 0.01).
- HD-Dual: slightly less homogeneous (HI 0.44 → 0.56) and +62% MU.
- HD-Single clinically unacceptable: lung +34%, PTV Dmax +41%.

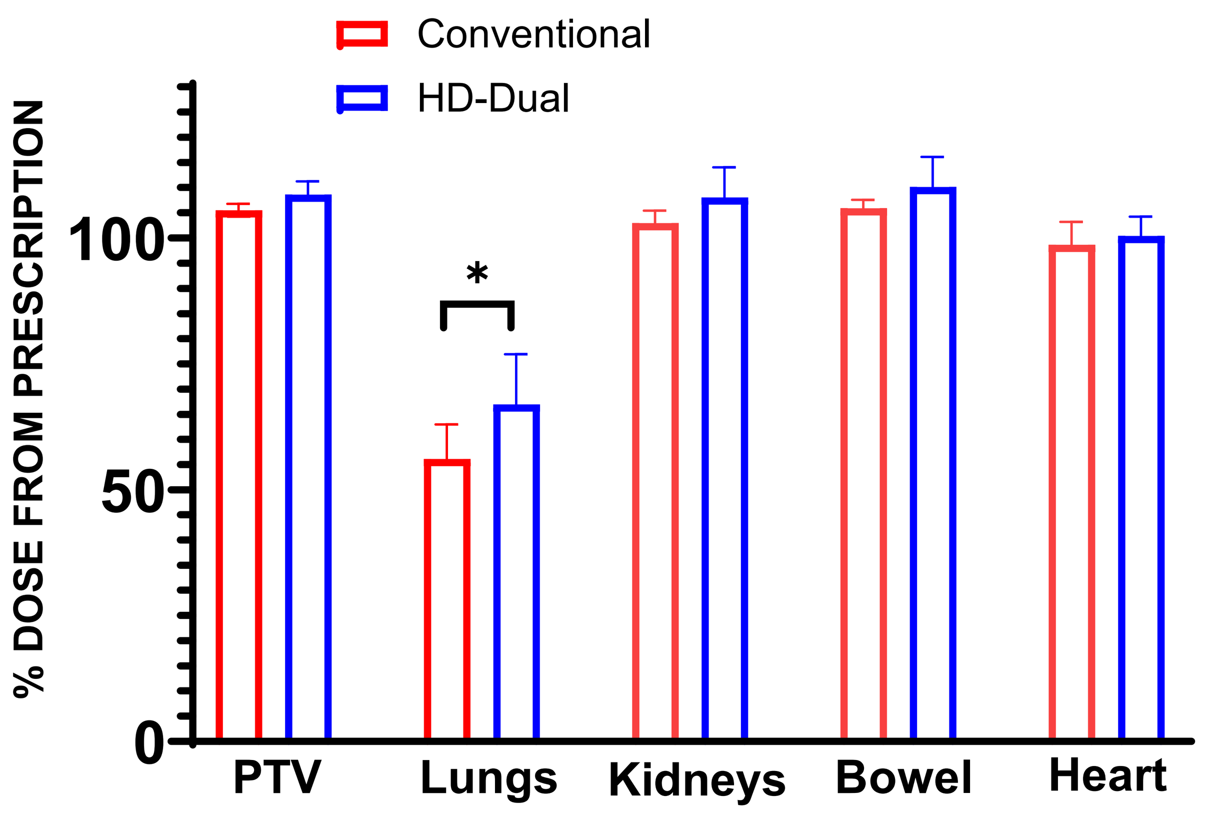
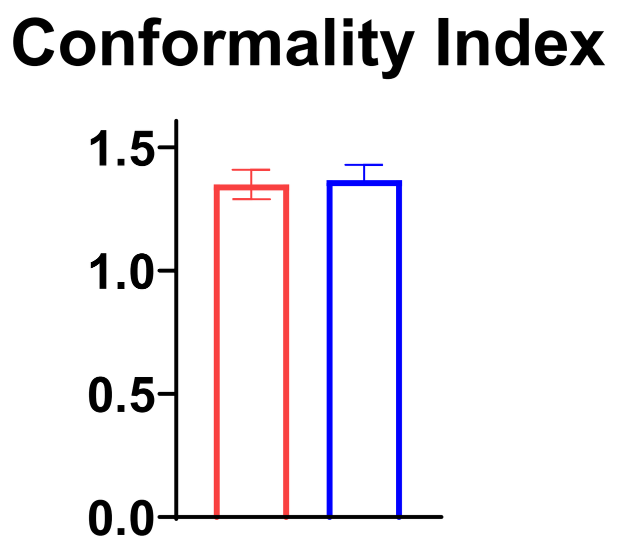


Figure 2. D50 (% of prescription): HD-Dual vs Conventional. Only lungs differ (*p = 0.01). Homogeneity index between Conventional and HD-Dual



Discussion

- HD-MLC can deliver VMAT TBI comparable to Millennium — but only with a dual-isocenter geometry.
- HD-Single fails (**Figure 3**): the 22 × 32 cm field cannot cover the lateral body, leaving cold regions (< 50% Rx); the optimizer overdoses the midline.
- A ±10 cm isocenter split balances coverage with full VMAT arcs and no collision; larger splits would force partial arcs.
- Lung D50 rose 10.8% with HD-Dual — likely extra modulation near split-field edges; smaller splits may reduce it.
- Even though HD-Dual was able to recreate plan dosimetrically. Mutliple isocenters will introduce additional imaging needed for patient setup with multiple shifts required for treatment increasing delivery complexity.
- On average the required number of MUs increased by 62% (3086 → 5007) which will lead to increased treatment times.
- **Limitations:** single institution, n = 10, planning study only; higher MU/integral dose may raise secondary-cancer risk and needs longer follow-up.

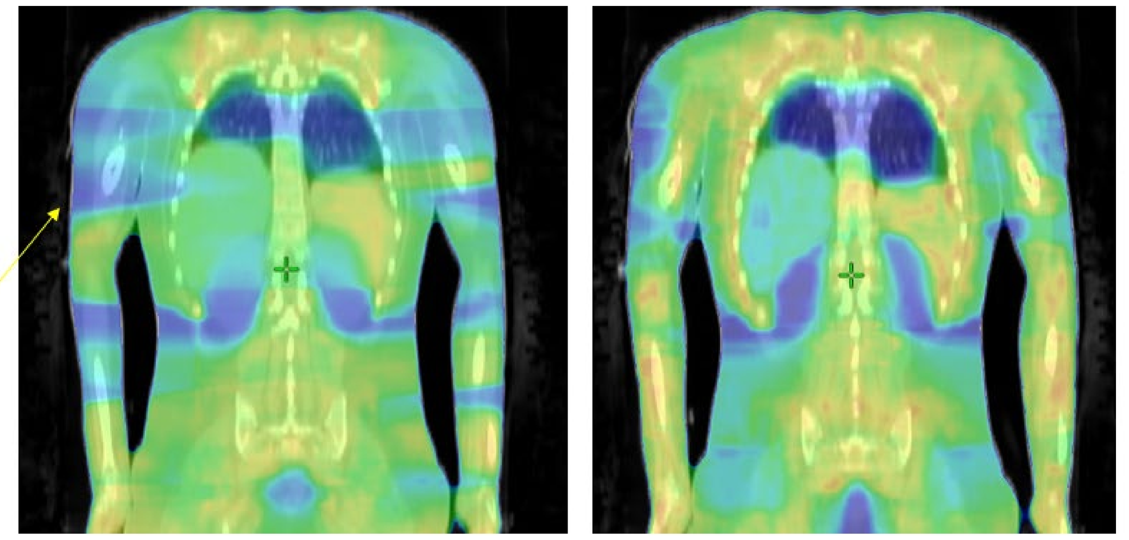


Figure 3. Visual display of the cold regions produced at the periphery of the patient cause by the lack of lateral field coverage

Conclusions

- HD-MLC VMAT TBI is feasible with a dual-isocenter technique, with quality comparable to large-field MLC systems.
- Trade-off: added complexity and treatment time — best reserved for clinics without a large-field MLC.

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