The Use of Low-Dose Radiation Therapy in Osteoarthritis: A Practical Joint-Specific Simulation and Planning Workflow

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

EMORY WINSHIP CANCER INSTITUTE
National Cancer Institute-Designated Comprehensive Cancer Center

ABSTRACT

- Developed a practical joint-specific LDRT simulation and planning workflow for osteoarthritis across different anatomic regions.
- Created reproducible CT simulation and MV photon planning templates for both small and large joints.
- Included alternative clinical-simulation workflows for patients with limited mobility or positioning challenges.
- Representative plans achieved strong target coverage, with V100% ranging from 95% to 99%.
- Hotspots remained within the intended homogeneity goal, with Dmax ranging from 109% to 115%.
- This workflow may help reduce barriers to safe, consistent, and reproducible LDRT implementation in the U.S.

INTRODUCTION

- Low-dose radiation therapy (LDRT) is an emerging treatment approach for benign inflammatory and degenerative joint conditions in the United States [1,2].
- Clinical implementation requires clear, joint-specific guidance for CT simulation, patient positioning, beam arrangement, bolus use, and shielding.
- Treating both small and large joints presents unique setup challenges, especially for patients with limited mobility or upper-extremity positioning restrictions.
- This work consolidates CT simulation and megavoltage photon planning guidance into a practical, clinic-ready workflow with existing RT infrastructure.
- Multiple validated setup pathways are included for challenging upper-extremity treatments, such as arms-over-head CT simulation versus clinical simulation using standing or stretcher-based positioning.
- The workflow supports consistent dosimetric intent across different simulation approaches by standardizing bolus placement, beam geometry, field coverage, and shielding practices.
- This guidance aims to improve treatment accessibility, reproducibility, and planning consistency for LDRT of small and large joints.

- A joint-based LDRT protocol was developed to standardize CT simulation orientation, immobilization, bolus placement, and simple MV photon beam arrangements for small and large joints.
- Foot/toes, ankle, knee, and elbow treatments used reproducible CT simulation setups with Vac-Lok immobilization, 0.5 cm bolus, and simple 6 MV opposed beam arrangements tailored to joint anatomy.
- Hand/wrist treatments were simulated with the treated hand(s) above the head using thermoplastic mask immobilization, with 0.5 cm bolus placed under and over the hand/mask.
- For patients unable to tolerate arms-up CT simulation, alternative clinical simulation pathways were implemented using standing or stretcher-based positioning, 6 MV PA fields, recorded hand thickness/SSD/field shape, and kV imaging or film verification.
- Hip, shoulder, and spine treatments used comfort-based head-first supine simulation with minimal immobilization, using 6–10 MV AP/PA fields for hip/shoulder and single PA fields for spine.

PLANNING APPROACH

- Planning templates standardized coverage of the symptomatic joint and peri-articular tissues using approximately 1.0–1.5 cm margins, 0.5–1.0 cm bolus as indicated, and selective nail-bed MLC shielding for hands/feet when appropriate.
- Plans were evaluated for target coverage using V100% for the contoured joint target, with a dose homogeneity goal of approximately +15%.

RESULTS

- The protocol library was finalized for foot/toes, ankle, hand/wrist, knee, elbow, hip/shoulder, and spine (CT-simulation and clinical-simulation).
- Representative MV plans using 0.5 Gy × 6 fractions (3 Gy total) demonstrated V100% of 97.9%–100.0% and Dmax of 104.1%–113.5% across joint sites (Table 1).
- Small joints were planned with 6 MV and 0.5–1.0 cm bolus, while deeper joints used 6/10 MV (hip without bolus). Figure 1 shows representative dose distributions and hotspot locations.

Table 1: Representative LDRT Planning Parameters and Dosimetric Summary by Joint Site.

SITE	SETUP	ENERGY	BOLUS	V100%	HOTSPOT (%)
FOOT/ANKLE	LATERALS	6X	0.5 CM	97.95	109.3
HAND/WRIST	AP/PA	6X	1.0 CM	97.94	112.5
KNEE	AP/PA	6X	1.0 CM	100.0	109.3
SHOULDER	AP/PA	6X	0.5 CM	98.12	104.1
HIP	AP/PA	6X	-	100.0	113.5

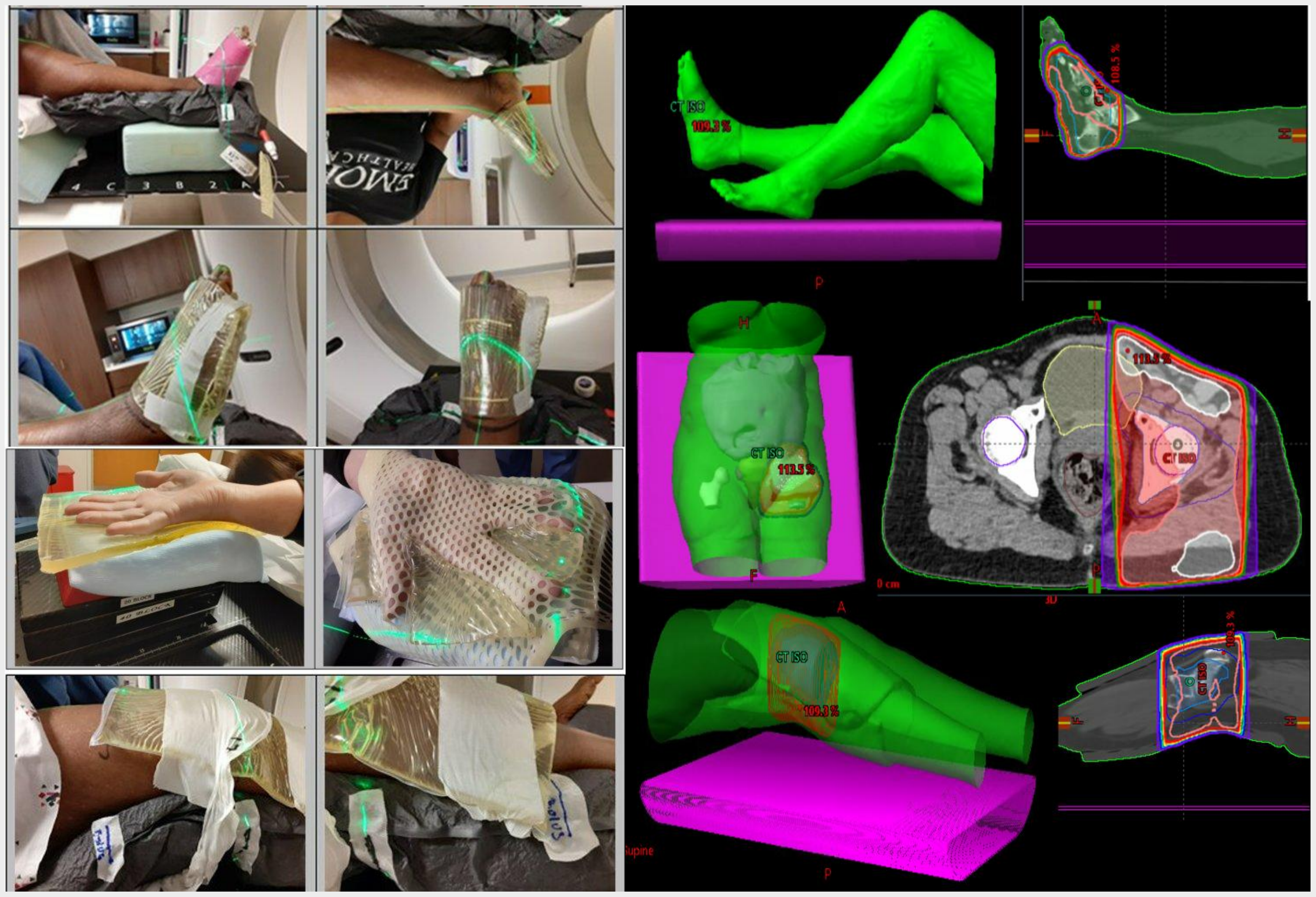

Figure 1: Representative low-dose radiotherapy simulation setups and treatment dose distributions for joint-based treatments.

CONCLUSIONS

A practical CT simulation and MV planning template library for LDRT in OA was developed across small and large joints, including contingency workflows for limited mobility. Representative plans achieved hotspot levels consistent with a +15% homogeneity objective, providing a reproducible approach that may reduce barriers to safe and consistent clinical adoption of LDRT for benign inflammatory indications. Future work will investigate streamlining of simulation and treatment setups for optimizing workflows for high patient throughput.

REFERENCES

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