Dosimetric Characterization of Rotational Total Skin Electron Therapy and Partial-Body Shielding Strategies

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ABSTRACT

Background/Purpose:
Rotational Total Skin Electron Therapy (TSET) in HDTSe mode offers dosimetric advantages for treating cutaneous malignancies, however, a comprehensive beam characterization at extended SSD and systematic evaluation of partial-body shielding configurations remain limited. This study characterizes beam properties of rotational HDTSe and compares near-patient versus gantry-mounted shielding strategies.

Methods:
A Varian TrueBeam (6 MeV HDTSe, 2500 MU/min) with a rotational platform at SSD = 380 cm was used. Field uniformity was assessed with a Farmer chamber over a field area of 188 × 80 cm². Longitudinal profiles were measured with radiochromic film on stacked solid water at 1.1 cm depth. PDD was acquired with an SNC 350p parallel-plate chamber, with dmax confirmed by TLD and film. Shielding profiles were compared for lead placed near-patient (~50 cm) and lead mounted on the gantry (~380 cm from phantom).

Results:
Field uniformity satisfied TG-30 and EORTC criteria. The open-field longitudinal profile was flat within ±5% to ± 7% over 120 cm. Dept of, dmax was found to be 3.6 mm; bremsstrahlung tail was <3% beyond 3 cm depth. Near-patient shielding produced a sharp dose transition over 15–20 cm (from ~1.9 Gy to near zero). Gantry-mounted shielding yielded resulted in a broad gradient, with ~40% dose bleed-through at the field edge.

Conclusions:
Rotational HDTSe beam characteristics meet established clinical benchmarks. Near-patient shielding provides sharp, reliable dose cut-off for partial-body treatments; gantry-mounted shielding is inadequate for dose conformity and is not recommended.

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INTRODUCTION

Total Skin Electron Therapy (TSET) treats cutaneous malignancies such as mycosis fungoides by delivering uniform superficial dose across the entire body surface. Rotational TSET — in which the patient rotates on a motorized platform within a single large electron field — eliminates multi-position setups required by the Stanford six-field technique and offers more consistent circumferential coverage. High-dose-rate total skin electron (HDTSe) mode on modern linacs can offer practical treatment times at extended source-to-surface distances (SSD).

Purpose
1. Characterize beam properties of rotational HDTSe delivery at clinical SSD (380 cm): field uniformity, longitudinal profiles, PDD, and key beam parameters.
2. Compare near-patient vs. gantry-mounted lead shielding for partial-body TSET applications.

METHODS AND MATERIALS

Beam Configuration Varian TrueBeam, HDTSe mode, 6 MeV, 2500 MU/min. Gantry at 270°, collimator at 45°, jaws at 40×40 cm², MLC fully retracted. Custom aluminum-lead flattening filter (7 cm diameter, 1.6 mm Al + 0.1 mm Pb) in upper wedge slots. Patient rotational platform (Radiation Products Design) at SSD = 380 cm.

Field Uniformity Farmer-type ionization chamber (SNC600c) over 188×80 cm², 10 cm horizontal / 30 cm vertical intervals. Criteria: AAPM TG-30 (±8% vertical, ±4% horizontal) and EORTC (±10%).

Longitudinal Profiles Gafchromic EBT4 radiochromic film at 5 cm intervals on stacked solid water, 1.1 cm depth buildup, 6000 MU. Three scenarios: no shield (open), near-patient shield (~50 cm away from phantom), gantry-mounted shield (~380 cm from phantom). Both shielding configurations used 6 mm Pb (Figure 1).

Percentage Depth Dose SNC 350p parallel-plate chamber in solid water at 380 cm SSD. dmax confirmed by TLD (wax bolus layering) and Gafchromic film interleaved in Rando anthropomorphic phantom. Beam parameters (R_{50}, Rp, bremsstrahlung tail) compared to standard clinical 6 MeV per AAPM TG-25.

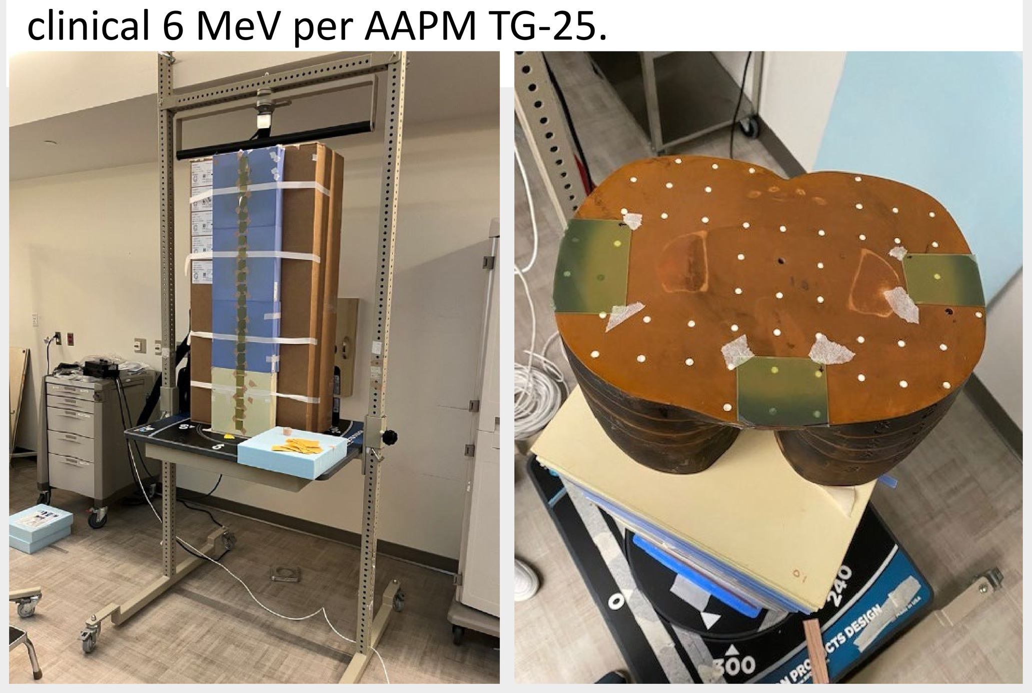

Figure 1. Setup for profiles (left) and depth dose curves (right) using radiochromic film.

RESULTS

Field Uniformity Uniformity criteria (TG-30, EORTC) were met across the central treatment field. An underdosage in field corners was observed — a known limitation of a large single field technique at 380 cm SSD. Horizontal profiles were flat within ±4%; the vertical profile was uniform within ±8% over the central region (Figure 2).

Table 1. Beam characteristics for the 6 MeV electron beam in HDTSe mode in a Varian TrueBeam. *Film and TLD measurements under rotational delivery.

Parameter	Clinical 6 MeV $SSD_{100\,cm}$ 20x20	HDTSe 6 MeV SSD_{100cm} 40x40	HDTSe 6 MeV SSD_{380cm} 40 x 40 Static	HDTSe 6 MeV SSD_{380cm} 40 x40 Rotational
Dmax (cm)	1.30	1.25	0.9	0.36*
R_{50} (g/cm²)	2.38	2.36	1.85	N/A
Rp (g/cm²)	3.01	2.77	2.12	N/A
Brems. Tail (%)	0.6	1.05	2.7	< 3*

The shallow dmax of 3.6 mm under rotational conditions (vs. ~9 mm stationary) reflects the continuously varying angles of electron incidence during platform rotation. The elevated bremsstrahlung tail relative to standard 6 MeV are due to filter-induced beam hardening and photon dose accumulation.

Open-Field Longitudinal Profile Doses were flat within ±5–7% over 120 cm along the superior-inferior axis — well within the ±10% TSET uniformity criterion. Confirms flattening filter performance at 380 cm SSD (Figure 3).

Shielding Comparison
Near-patient shielding (~50 cm from surface): Dose was uniform at ~2.0–2.1 Gy up to the shield edge, then dropped sharply from ~1.9 Gy to near zero over 15–20 cm. Near-complete attenuation achieved by ~105–110 cm lateral of the central axis. A <5% backscatter perturbation was noted proximal to the shield edge — clinically insignificant.

Gantry-mounted shielding (~380 cm from surface): No defined dose transition was observed. Dose fell only gradually along the whole length of 120 cm, reaching ~0.8 Gy (40% of unshielded dose) at 120 cm under the shield. The geometric shadow was entirely washed out by multiple Coulomb scattering over the extended path.

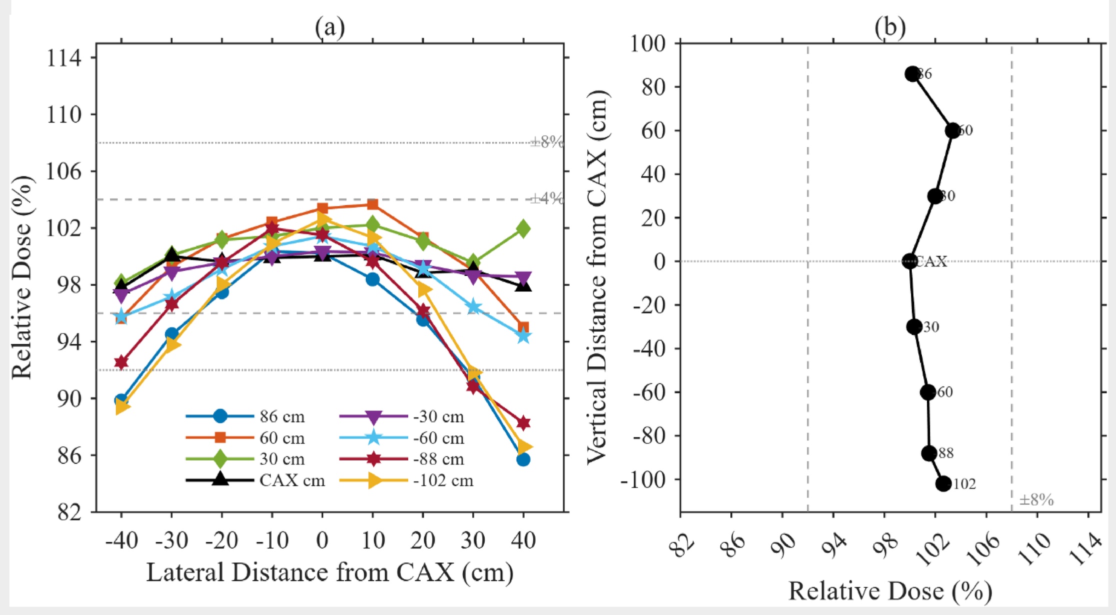

Figure 2. (a) Horizontal and (b) vertical relative dose profiles across the TSET treatment field. Horizontal profiles are shown at 10 cm intervals from the central axis (CAX). Dashed lines indicate the ±4% and ±8% uniformity limits specified by AAPM TG-30.

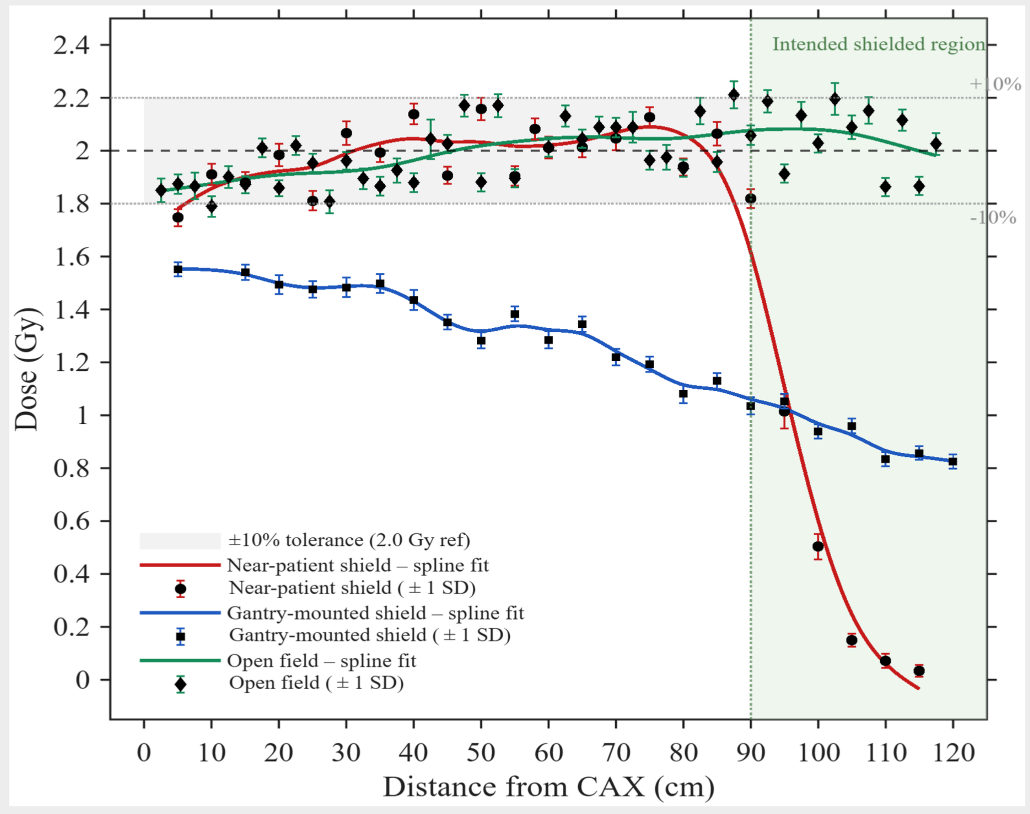

Figure 3. Longitudinal dose profiles measured along the patient axis for three configurations: open field (green), gantry-mounted lead shielding (blue), and near-patient lead shielding (red). A 6 mm lead shield was used in both shielded configurations. Horizontal shaded grey band represents ±10% tolerance region about the 2.0 Gy prescription dose. The shaded green region indicates the intended shielded area lateral to the shield edge (90 cm from the central axis). Error bars represent ±1 standard deviation propagated from red-channel optical density uncertainty across the film dosimetry region of interest.

DISCUSSION

Field uniformity met AAPM TG-30 and EORTC criteria, with underdosage in the field corner consistent with published single-field rotational TSET data. The rotational dmax of 3.6 mm — shallower than the ~9 mm observed under stationary conditions — reflects oblique electron incidence during rotation and must be accounted for in buildup protocol design. The bremsstrahlung tail below 3% is consistent with published filtered rotational beam data and is clinically acceptable.

Gantry-mounted shielding left 40% residual dose under the intended shielded region — a direct consequence of multiple Coulomb scattering over the ~330 cm air path, and clinically unacceptable over a multi-fraction course. Near-patient shielding preserved geometric shadowing with a sharp 15–20 cm transition and near-complete distal attenuation and remains the only dosimetrically sound option for partial-body rotational TSET at extended SSD.

CONCLUSIONS

Rotational HDTSe delivery met established dosimetric benchmarks: TG-30/EORTC field uniformity, rotational dmax of 3.6 mm, and bremsstrahlung below 3%. Near-patient shielding produced a sharp, reliable dose cut-off; gantry-mounted shielding yielded unacceptable bleed-through and is not recommended for partial-body TSET.

REFERENCES

1. Podgorsak et al. *Med Phys.* 1983 | AAPM TG-30, TG-25 | Reynard et al. *JACMP* 2008 | Broderick et al. *JACMP* 2025