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Teaching Case

Clinical application of lying-on-the-floor total skin electron irradiation for frail patients with cutaneous lymphoma: An emphasis on the importance of in vivo dosimetry

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Introduction

Total skin electron irradiation (TSEI) is an effective option for cutaneous T-cell lymphoma (CTCL).[1,2] Two conventional methods used to deliver TSEI are the Stanford multiple dual field technique and the McGill rotational technique[3,4]; however, both techniques require patients to stand for 10 to 30 minutes and cannot be used in non-ambulatory patients. Our group has previously described technical parameters for "lying-on-the-floor" total skin electron beam therapy for nonambulatory patients.[5] We now report clinical implementation of this technique in a non-ambulatory patient with progressive CTCL with particular emphasis on the critical importance of in vivo dosimetry.

Case presentation

A 67-year-old male with progressive CTCL was seen for consideration of palliative radiation therapy 14 months

Conflicts of interest: None.
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after his original diagnosis. Symptoms and findings at the time of diagnosis had included an intensely pruritic, diffuse, erythematous truncal rash. Multiple biopsies demonstrated atypical dermatotropic lymphoid infiltrate consistent with CTCL. He had received 3 different courses of systemic therapy including: cyclophospha-mide, hydroxydaunorubicin, vincristine, and prednisone chemotherapy; romidepsin; and bexarotene before pre-senting for radiation therapy. He presented with extensive disease, including multiple ulcerative lesions (Fig 1). The plantar surfaces of his feet were spared by his disease process. He was treated initially with a course of con-ventional standing TSEI without supplemental irradiation to the soles of the feet, 16 Gy in 4 fractions given approximately every 7 to 10 days.[6]

Initial TSEI was well tolerated; 2 months later, he had near complete response (Fig 2) of his cutaneous disease except for the soles of his feet where he had progression. A total of 8 Gy in 2 fractions to this area resulted in complete response. He was then started on bendamustine and methylprednisolone after further workup revealed innumerable pulmonary nodules histologically confirmed to be T-cell lymphoma.

Approximately 4 weeks later, he returned for re-evaluation with extensive cutaneous recurrence. His

pulmonary disease showed interval improvement, suggesting a mixed response to the bendamustine and methylprednisolone. His overall condition had deteriorated and he was no longer able to stand for treatment. As such, a lying-on-the-floor TSEI technique was recommended. He was treated using this technique with an additional 12 Gy in 3 fractions, in which each fraction was delivered every 7 to 10 days (minor variation resulted from patient and physician availability). His cutaneous disease was well controlled with results similar to Fig 2. Two additional brief courses of single fraction (4 Gy) TSEI were sufficient to maintain skin integrity until the patient died of respiratory failure resulting from progressive pulmonary involvement by his lymphoma 6 months after his initial radiation oncology consultation.

Lying-on-the-floor TSEI technique

Other investigators have described techniques for total skin electron beam therapy for nonambulatory patients.[4,7] A major modification in our technique is the use of a customized copper flattening filter to improve treatment field uniformity, which eliminates the need for field junctioning and minimizes setup time.[5] This technique also does not require match lines. Treatment was delivered with 6-MeV electrons. A polycarbonate spoiler (2 m × 1 m × 4 mm) was used for electron scatter and beam energy degradation.

The patient setup is depicted in Figs 3 and 4. The 6 conventional standing positions[1,4] are reproduced on the floor and described here. For the anteroposterior (AP) and posteroanterior (PA) positions, the patient's umbilicus is positioned either supine or prone directly below the isocenter with the skin surface about 5 cm below the polycarbonate spoiler, and the patient is oriented perpendicular to the LINAC waveguide. The patient lies on a thin mattress (about 3 cm thick) with arms and legs

Figure 2   Patient 2 months after total skin electron irradiation.

partially away from the body and fingers spread apart. Three gantry angles of 0°, 60°, and 300° were used to provide optimal dose homogeneity for both the AP and PA positions. Monitor unit (MU) weighting for the gantry angles, which were empirically determined and described previously,[5] were $MU_{300°}$ equal to $MU_{60°}$, and $MU_{0°}$ equal to 0.41 $MU_{60°}$ to account for the fact that the $MU_{0°}$ delivers more dose per MU than the 60° and 300° beams. The left posterior oblique, right posterior oblique, left anterior oblique, and right anterior oblique positions are set up with the patient oriented parallel to the waveguide and the umbilicus at a distance of 230 cm from the isocenter, with a gantry setting of 300°. The polycarbonate spoiler is positioned adjacent to the patient as depicted in Fig 4.

Calibration of the treatment has also been previously described.[5] In brief, a parallel plate ion chamber (Advanced Markus Type No. TN34045; PTW, Freiburg, Germany) and solid water was used under standard reference conditions of a 10 × 10 cm^2 cone size, 100 cm source–skin distance, and 1.3 cm depth to obtain a cGy/nC conversion factor for the 6-MeV beam on high dose rate total skin electron mode. This provided a measured dose per unit charge collected in the chamber. The chamber and solid water was then put into a position more representative of the patient's anatomy during treatment. In our patient's case, this consisted of putting the chamber surface about 25 cm above the floor and the spoiler 5 cm above the chamber. Pragmatically, the chamber surface should be at the same point as the nominal prescription point, the umbilicus. We then use 30 × 40 cm^2 fields with the custom copper filter in place to scatter the electrons and deliver 1000 MU at gantry angles of 0°, 60°, and 300°. A similar procedure is performed for the oblique fields. The chamber and solid water is placed behind the spoiler again and the assembly is angled to 60° to mimic the oblique slope of the patient's body when lying down. This setup allowed us to determine the monitor units needed to deliver the prescription dose under ideal conditions.
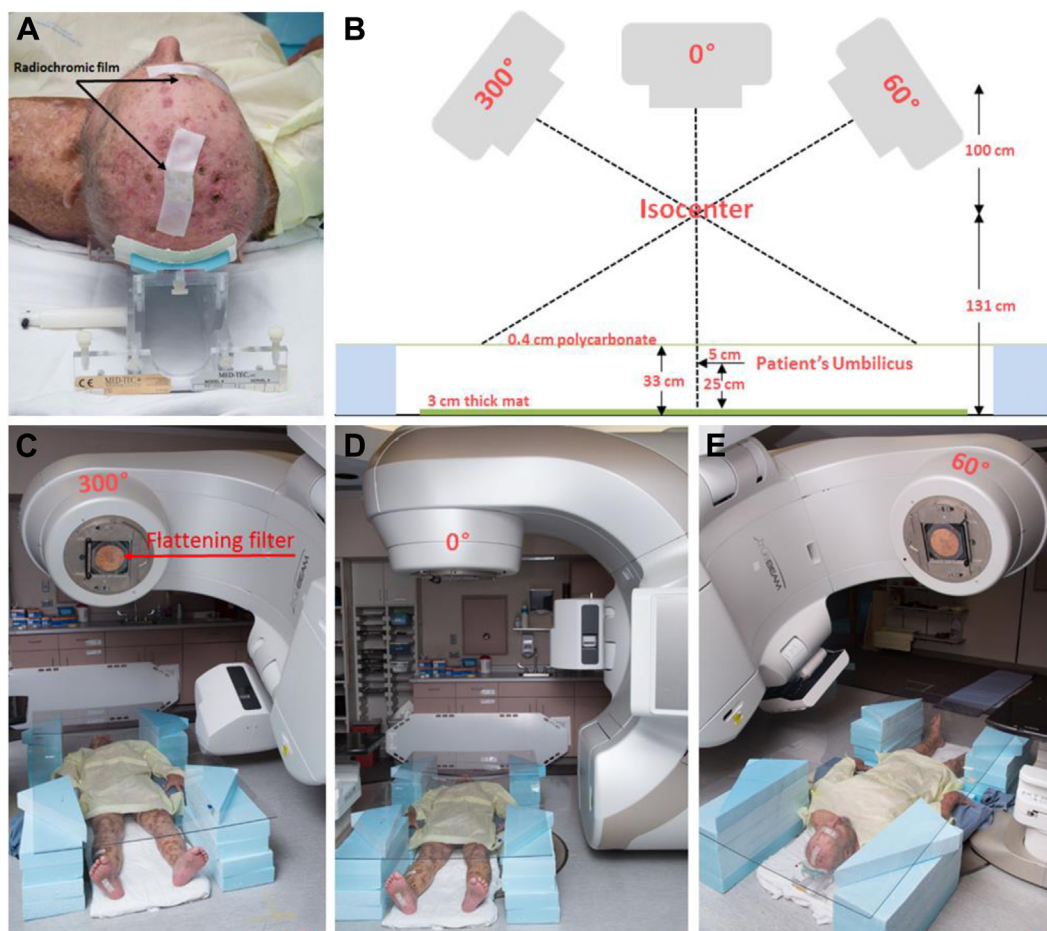

Figure 1   Patient's initial presentation to radiation oncology after 3 different courses of systemic therapy and before total skin electron irradiation.

Figure 3   Lying-on-the-floor total skin electron irradiation setup with the customized flattening filter technique. (A) Radiochromic film was used at various anatomical locations for in vivo measurements. (B) Schematic of anteroposterior and posteroanterior treatment fields (adapted from Deufel and Antolak[5]; used with permission). Note that only the anteroposterior setup is shown here. (C-E) The patient is oriented perpendicular to the LINAC waveguide (prone treatment fields not illustrated). His umbilicus was positioned directly below the central axis, 5 cm from the spoiler, and the gantry was angled to 300°, 0°, and 60°, respectively.

A body factor, which is essentially a multiplicative factor that takes into account the dose delivered to a point on the patient as they rotate through all of the positions, was also incorporated as previously described.[5] For body factor measurements, radiochromic film (Gafchromic EBT3; International Specialty Products Inc, Wayne, NJ) was affixed to the surface of the RANDO anthropomorphic phantom (The Phantom Laboratory, Salem, NY) in 60° increments. A body factor of 3.1 was calculated as the ratio of the summed dose delivered to a point on a standard anthropomorphic phantom transitioned through all treatment fields depicted in Figs 3 and 4 to the dose delivered from a single AP treatment field. However, we subsequently learned that the body factor on the phantom was larger than the patient's in vivo body factor.

In vivo dosimetric measurements allowed adjustments of dose delivery. In the previously published technical details of this approach, radiochromic film showed excellent agreement with ionization chamber results, and

a film calibration curve showed that the standard deviation of dose (200 cGy delivered) was <1.3% between any given piece of film.[5] Verification of the radiochromic film's accuracy and reproducibility using the lying-on-the-floor technique was demonstrated by previously comparing the normalized dose by anatomic site in both the Stanford standing technique and the lying-on-the-floor technique.[5] These measurements were made by taping pieces of $2 \times 2 \; cm^2$ radiochromic film onto the patient's skin at representative locations on the head and neck, torso, and extremities. Setup time limitations made it impractical to measure all sites for every treatment. The radiochromic film was covered with a layer of plastic wrap so that the film itself did not come into direct contact with the patient's skin and cleaning of the film was not necessary before analysis. Doses obtained from in vivo measurements are presented in Table 1. Dosimetry was obtained at the level of the umbilicus anteriorly, posteriorly, and lateral to the left of the umbilicus at every treatment. Eighteen other sites
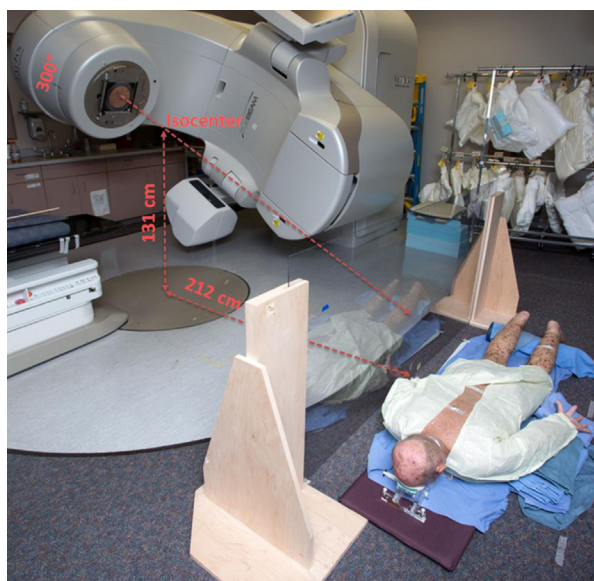
Figure 4   The left posterior oblique, right posterior oblique, left anterior oblique, and right anterior oblique positions were delivered with the gantry rotated to 300° with the patient oriented parallel to the LINAC waveguide and the umbilicus approximately 230 cm from isocenter (supine treatment fields not illustrated).

were sampled for 1 or more treatments. The average in vivo dose measurement was 78% of the prescription dose of 400 cGy for the first fraction. Monitor units were cautiously increased by 10% for the second treatment with a goal of achieving an average dose of 90% of the prescription. Furthermore, during the second treatment, additional films were used to measure an in vivo body factor and check the delivered dose for each field. The body factor was calculated in vivo to be 2.7 as opposed to the 3.1 measured with a rigid phantom, approximately 15% lower. The average in vivo dose measurement for the second fraction was 87% of the prescribed 400 cGy. The MUs were increased by an additional 15% for the third fraction, resulting in an average in vivo dose measurement of 99% of the prescribed 400 cGy.

Discussion

In vivo dosimetry was critical for successful treatment delivery. MUs delivered were systematically increased on progressive treatments according to the in vivo measurements obtained with radiochromic film. Second,

Table 1   In vivo dosimetric measurements

Location	Fraction 1 (400 cGy)		Fraction 2 (400 cGy)		Fraction 3 (400 cGy)	
	Dose (cGy)	% of 400 cGy	Dose (cGy)	% of 400 cGy	Dose (cGy)	% of 400 cGy
Umbilicus, anterior	320	80	363	91	396	99
Umbilicus, left anterior oblique*	232	58	331	83	349	87
Umbilicus, right anterior oblique*			302	76	301	75
Umbilicus, posterior	315	79	339	85	401	100
Umbilicus, left posterior oblique*			377	94	466	117
Umbilicus, right posterior oblique*			348	87	366	92
Upper back			359	90	421	105
Posterior neck	406	102	412	103		
Right lateral shoulder			309	77	349	87
Right forearm	274	69	309	77		
Left anterior thigh			328	82		
Left posterior calf			348	87	395	99
Left dorsal foot	327	82				
Left anterior wrist					454	114
Anterior chest					398	100
Right anterior thigh					399	100
Right lateral hip	363	91			458	115
Right anterior shin					424	106
Right posterior calf	276	69				
Forehead	293	73			335	84
Average	312	78	349	87	394	99

* For these sites, in vivo dosimetry was obtained at the intersection of the central axis and the patient's body for the left anterior oblique, right anterior oblique, left posterior oblique, and right posterior oblique fields.

an extensive simulation during the patient's initial visit was not done before the first treatment, and would have better defined the treatment conditions. There was approximately a (1.1*1.15)/0.99 = 1.28 or 28% discrepancy between the expected and actual doses observed in vivo. Of the 28%, we believe 15% may be attributed to the patient-specific body factor. The remainder of this dose discrepancy may be attributed to setup variation, which we propose could largely be mitigated by a thorough simulation process. Specifically, the proposed simulation would have included detailed measurements of the patient's physical dimensions on the treatment floor. The AP/PA thickness, the lateral width, and the distance from the patient's skin surface (both supine and prone) to the LINAC would have been useful to accurately represent the locations to which the calibration parallel plate chamber should be positioned. After cautiously increasing the monitor units after the first treatment, the discrepancy between the in vivo measured dose and the expected dose prompted further evaluation of another potential contributing factor: the body factor. The patient-specific body factor during the actual treatment was 2.7 versus 3.1 measured on a rigid anthropomorphic phantom. Using the phantom during the commissioning of this technique, the estimated body factor was approximately 15% greater than the in vivo measured factor and adjustments had to be made to the treatment setup on the second day to account for the patient's body habitus.

Teaching case: Key learning points

This teaching case demonstrates that TSEI may be effectively used in nonambulatory patients using a lying-on-the-floor technique. This case also shows that simulation before the first treatment and in vivo measurements are critical for accurate delivery of dose using this technique.

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