

A Technique for Pediatric Total Skin Electron Irradiation

Background

Total skin electron irradiation (TSEI) is routinely used for the treatment of cutaneous T-cell lymphoma. Recently, two pediatric patients with recurrent acute myelogenous leukemia presented with leukemia cutis (LC) and required electron irradiation to the total skin. A particular challenge in implementing a clinical pediatric TSEI program is the difficulty in delivering a uniform dose to the total skin of a sedated infant. This report describes the commissioning and quality assurance (QA) procedures for implementing a clinical TSEI program for the treatment of LC in pediatric patients at the University of Texas Southwestern (UTSW) Medical Center at Dallas. This includes dosimetric commissioning as well as fabrication of specialized equipment used to hold sedated pediatric patients in a modified total body irradiation (TBI) stand.

Methods and Results

This pediatric TSEI approach is based on a modified Stanford technique using six dual electron fields [1-3]. Due to the smaller size of pediatric patients and the sedation requirement for consistent positioning, additional equipment and dosimetric commissioning measurements were required.

1. Dosimetric commissioning and quality assurance

1.1. Adult TSEI field flatness and calibration

At our institution, adult TSEI patients are treated with six dual-fields (anterior, posterior, and four obliques) using gantry angles of $\pm 20^\circ$ from the horizontal axis. These angles are used to achieve a uniform dose ($\pm 10\%$) over a region of more than 170 cm while simultaneously reducing the total body dose from the mostly forward peaked contaminant bremsstrahlung photons. Absolute calibration of the machine output for TSEI is performed according to AAPM protocol [4].

1.2. Phantom measurements for pediatric TSEI commissioning

Since the pediatric patient size is much smaller than that of the adult patient, it is necessary to determine whether the *B*-factor (the factor relating the skin and calibration point doses) for adult patients is applicable to pediatric patients. A custom made cylindrical acrylic phantom of 20 cm diameter and 25 cm height was used for this evaluation. Optically stimulated luminescent (OSL) dosimeters were placed on multiple locations at the surface of the phantom and uniformly irradiated to a nominal dose of 50 cGy, based on the adult TSEI treatment protocol and *B*-factor. The dose delivered to the surface of the phantom was measured to be 53.7 cGy on average, 7.3% higher than the nominally delivered dose, suggesting an increased *B*-factor should be used when treating pediatric TSEI patients. For a smaller given diameter, the two oblique beams will contribute more dose to a particular point, thus it is reasonable that the *B*-factor for the pediatric geometry increases compared to the adult TSEI technique. This inverse relationship of *B*-factor with patient diameter has been reported previously [5].

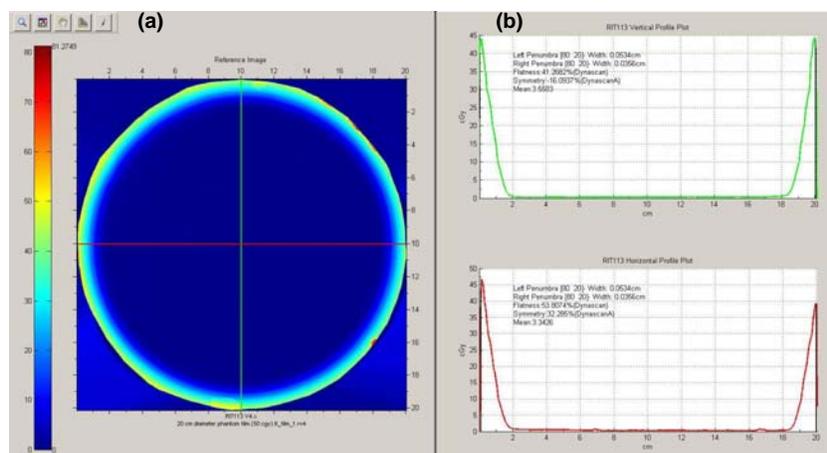


Figure 1. Film measurement for the composite TSEI beam. (a) An XV film was uniformly irradiated with 50 cGy dose and (b) two orthogonal profiles indicates the dose penetration of the TSEI beam.

2. Treatment design

2.1. Equipment

In order to position sedated pediatric patients at the six angles required for TSEI, a rotating plate/harness system was constructed and attached to a custom made frame used for Total Body Irradiation (TBI) treatments (Figure 2). A

XV film was sealed within a cylindrical solid water phantom at mid-phantom height. The film was aligned horizontally along the central axis and a dose of 50 cGy prescribed to the surface dose delivered using the TSEI protocol. Figure 1 shows the dose distribution on the central axial slice. Based on the dose profile of the film, it can be observed that the periphery of the film was uniformly irradiated from the degraded 6 MeV electron beams. The electrons have a maximum range of approximately 2 cm, with the maximum dose occurring at the phantom surface.

central bar was mounted on top of the TBI frame, parallel to the beam axis, and an aluminum rotating plate was attached to the bar. Holes were drilled on the outer rim of the rotating plate to facilitate patient positioning at 60° interval for the 6 positions. A bolt is used to index the rotating plate to the top central bar at each position to ensure the positioning accuracy. The entire plate can be moved along the central bar to maintain a constant patient to spoiler distance of 25 cm at the central beam axis for each position.

A custom made harness was sewn to hold the patient vertically. The harness attaches to the rotating plate with four belts which loop through carabiner clips. The lengths of the belts were constructed such that the patient umbilicus is centered along the horizontal beam axis. The harness was made from a single layer cloth to minimize attenuation of the electron beam yet maintain enough strength to support an infant. To ensure patient safety during treatment, the strength of the harness was verified by placing weights inside the harness while hanging on the rotating plate for at least one hour.

2.2. Treatment procedure

Two infants have been treated since commissioning this pediatric TSEI technique. Each patient was scheduled to receive 16 Gy over the entire treatment course for 8 cycles. Each cycle consists of two treatment days with three dual-fields each (AP, LPO, RPO on the first day and PA, LAO, RAO on the second day).

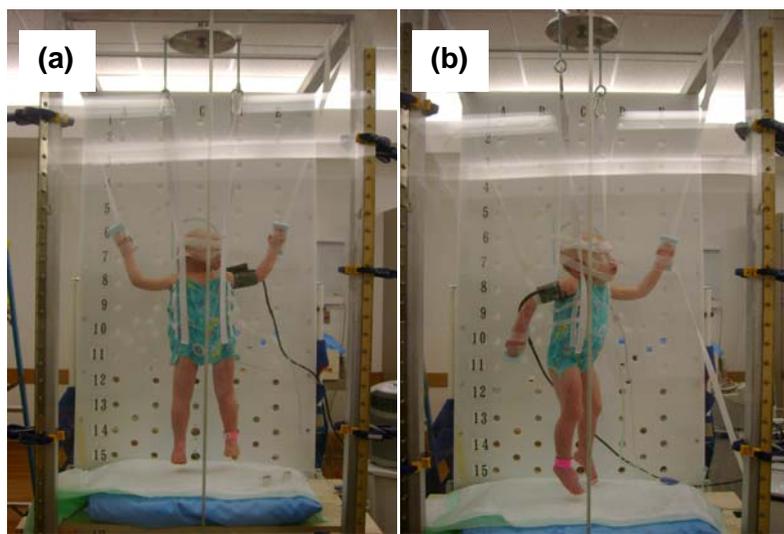


Figure 2. The patient in treatment positions for (a) PA and (b) RAO locations.

The patient was anesthetized and placed within the harness while on a gurney. The patient was carefully lifted into place while the harness belts were clipped onto the carabiners attached to the rotating plate. The patient's head was either supported by a piece of acrylic plate placed opposite of the beam or taped in place to the harness belts. Patient arms were positioned in similar positions as for adult TSEI patients (Figure 2). After the patient position was set, the distance from the patient to the spoiler was measured, and the rotating plate was moved along the bars of the TBI stand to the desired 25 cm spoiler-to-patient distance.

Doses for two consecutive days of treatment were measured and combined to give the total dose delivered during one cycle. Of the five locations measured on the first patient, the averaged dose was 201.9 cGy, which was 1.0% higher than the prescription dose and within our accepted tolerance (Table 1). For the second pediatric TSEI patient, the average dose determined by the OSL detectors was 198.3 cGy, 0.8% lower than the prescription. However, with this patient, individual regions including the top of the head and the inner thighs exceeded our $\pm 10\%$ dose uniformity criteria. An electron boost was concurrently administered to the top of the patient's head, which had visible lesions, for the second half of the treatment course based at the physician's request.

Table 1. OSL detector dose measurements for cycle two of first patient for reduced MUs

OSL Detector Location	AP+LPO+RPO (cGy)	PA+LAO+RAO (cGy)	Total Dose (cGy)	% Diff from Rx
Forehead	96.1	117.2	213.3	6.6
Posterior of Head	121.9	84	205.9	3.0
Umbilicus	79.1	117.3	196.3	-1.8
Posterior of Umbilicus	125.6	72.6	198.2	-0.9
Back of Right Hand	70.5	125.3	195.7	-2.1
Average			201.9	1.0

Selected references

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