Practical Radiation Oncology (2013) **xx**, xxx–xxx

practical radiation oncology
pro
www.practicalradonc.org

Original Report

A novel approach to total skin irradiation using helical TomoTherapy

Arman Sarfehnia PhD [a,*], Emily Poon PhD [a], Stephen D. Davis PhD [a], Adam Fleming MD [b], David Mitchell MD [b], Carolyn R. Freeman MD [c]

[a]*Department of Medical Physics, McGill University Health Centre, Montreal, Quebec, Canada*
[b]*Department of Hematology/Oncology, McGill University Health Centre, Montreal, Quebec, Canada*
[c]*Department of Radiation Oncology, McGill University Health Centre, Montreal, Quebec, Canada*

Received 21 August 2013; revised 7 October 2013; accepted 9 October 2013

Abstract

Purpose: To describe our experience with a novel technique for total skin irradiation using helical TomoTherapy (Accuray, Sunnyvale, CA).

Methods and materials: An infant with refractory acute myelogenous leukemia with extensive cutaneous involvement was given total skin irradiation using inverse-planned helical tomotherapy. Quality assurance tests to determine the deliverability of the technique and the accuracy of dose estimation at the superficial skin level were devised and performed. Daily megavoltage imaging, tomotherapy plan adaptive evaluation, in vivo skin dose measurements, and cumulative dose summation were tools employed to assess the quality of treatment and positioning reproducibility on a daily basis.

Results: The quality assurance checks showed that tomotherapy can indeed be used for total skin irradiation in cases where conventional electron treatment delivery is not possible. However, the overestimation of absorbed dose near surface by the treatment planning software must be quantified and taken into account using in-phantom and in vivo dosimetry techniques with appropriate detectors. Daily imaging allows for superior positioning, while daily plan adaptive and dose summations based on the plan adaptive calculations allow for evaluation of the treatment delivery.

Conclusions: An infant has been treated successfully using helical TomoTherapy for total skin irradiation prior to allogeneic stem cell transplant. The course of treatment was uncomplicated and the patient is doing well more than 15 months following therapy.

Introduction

Total skin irradiation is normally performed at our institution using a rotational technique with the patient standing on a rotating platform at an extended source-to-surface distance.[1-3] A high-dose-rate 6 MeV electron beam is used with a custom-built flattening filter to ensure

Conflicts of interest: None.

* Corresponding author. McGill University Health Centre, Department of Radiation, Oncology, Rm L5-112, 1650 Cedar Ave, Montreal, Canada, QC H3G 1A4.

E-mail address: asarfehnia@medphys.mcgill.ca (A. Sarfehnia).

1879-8500/$ – see front matter.

a degraded beam that is relatively uniform in the central 80% of the large patient field size. Our requirement for uniformity is ±10%, although our most recent in-air measurements have shown ±3% uniformity.

The decision to use total skin irradiation as part of the preparatory regimen for a stem cell transplant for an infant with refractory acute myelogenous leukemia (AML) with extensive cutaneous involvement therefore posed a challenge. Our solution was to develop a technique using intensity modulated image guided radiation therapy using 6 MV photons on a helical TomoTherapy (Accuray, Sunnyvale, CA) unit. To the best of our knowledge, such an approach has not been previously described in the literature.

Methods and materials

Our patient

The patient presented to hospital at 10 months of age with fever, respiratory congestion, and an extensive nodular skin rash. He was found to be mildly anemic, with severe neutropenia. He had no previous medical history except for recurrent upper respiratory tract infections. His skin surface was extensively covered with a variety of lesions, from superficial scaly patches to thicker erythematous nodules, with relative sparing of the scalp. On physical examination and imaging, there was no evidence of lymphadenopathy or organomegaly.

Biopsy of a nodular skin lesion was positive for a leukemic infiltrate and a bone marrow biopsy showed acute myeloid leukemia (French-American-British [FAB] classification M5, acute monocytic leukemia). His cerebrospinal fluid showed many mononuclear cells and it was not possible to rule out central nervous system involvement by leukemia. He was admitted and treated with intensive chemotherapy as per the current Children's Oncology Group protocol (AAML1031) with cytarabine, daunorubicin, etoposide, mitoxantrone, and bortezomib. Based on an excellent marrow response at the end of induction cycle 1, he was stratified as low-risk and received a total of 4 chemotherapy cycles as per protocol. His skin lesions markedly improved and disappeared during the treatment phase. However, skin nodules reappeared within 2 weeks of completing his treatment and a skin biopsy performed approximately 1 month after chemotherapy was positive for leukemia cells. Bone marrow biopsy showed 6% blast cells. His cerebrospinal fluid was negative.

He was admitted for reinduction chemotherapy ("FLAG"; fludarabine, cytarabine, and filgrastim).[4] The skin lesions continued to progress over the following month, covering his entire body surface. The decision was made to treat him with stem cell transplantation using his brother's stored umbilical cord blood as a stem cell source. Due to the refractory skin disease, it was decided to use a conditioning regimen that included radiation therapy, to be given in 3 phases: first, total skin irradiation with a total dose of 14 Gy given in 7 daily fractions (2 Gy per fraction), then craniospinal radiation therapy with a single dose of 1.8 Gy, and then finally total body irradiation (TBI), with a total dose of 10 Gy given in 5 fractions (a single fraction on the first day of treatment and then twice daily on each of the following 2 days).

Total skin irradiation technique

Planning

The patient underwent computed tomography (CT) simulation under anesthesia in the supine position immobilized in a full body Vac-Lok cushion (Civco, Kalona, IA) along with a thermoplastic head mask. The whole skin surface was contoured and the planning target volume (PTV) was defined as a 3 mm rim of skin and subcutaneous tissue. Due to technical difficulties with accurate and reproducible placement of bolus, we chose not to use any bolus for treatment. Instead, we relied on in vivo film dosimetry for accurate surface dose measurement.

Optimization was performed using TomoTherapy, version 4.0.4 software. A field width of 5.0 cm, a pitch of 0.287, and modulation factor of 2.5 were used. Four concentric rings of 5-mm width each were drawn inside the larger PTV ring. These acted as optimizing structures and were used to force the dose to drop at an acceptable rate (Fig 1). The maximum doses for the rings were set at 17.9, 17.0, 16.7, and 16.0 Gy. Complete blocks at the center of the brain, abdominal, and thoracic cavity were also used to further minimize beams traversing through the patient and force the TomoTherapy to deliver tangential beams along the outer contour for the most optimal solution.

Delivery

TomoTherapy-based total skin therapy relies heavily on appropriate positioning of the patient as well as motion management. Accuracy in positioning was accomplished through the use of the couch-indexed Vac-Lok cushion and head mask. Daily full body megavoltage imaging using MVCT scans were performed to ensure appropriate positioning and monitor any weight changes or deviations of the body contour from the original kVCT.

Verification techniques

Prior to patient treatment

To evaluate the accuracy of surface dose estimation by the treatment planning system (TPS), a planned dose of 2 Gy was delivered along the 3-mm rim of a cylindrical phantom. Several pieces of radiochromic film (GafChromic EBT3; Ashland, Inc, Covington, KY) film were taped onto the phantom during the delivery. The measured dose