A case study of total marrow irradiation using VMAT

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ABSTRACT

Total marrow irradiation (TMI) was developed as an alternative treatment technique to total body irradiation (TBI) for myeloablation in patients diagnosed with conditions as varied as leukemia, lymphoma, and amyloidosis. TMI was originally delivered by helical tomotherapy, but some centers have experimented with volumetric modulated arc therapy (VMAT) delivery, a crucial step in making TMI more accessible. Currently, TMI administered by VMAT is in several facilities around the U.S. but is much less prevalent than it could be. The purpose of this study is to detail the process of TMI from simulation to planning and treatment based on a retrospective study of a 40-year-old male patient diagnosed with chronic myeloid leukemia.

Introduction

Developed thirty years ago, TBI is used as a conditioning regimen for patients undergoing hematopoietic cell transplantation.[1] However, TBI can cause numerous side effects including alopecia, diarrhea, nausea, fatigue, and mucositis.[2] The use of TBI declined due to these side effects as well as the introduction of non-TBI myeloablative conditioning regimens.[1]

Intensity-modulated radiation therapy (IMRT) and VMAT planning for TBI is known as TMI and was first used in 2005.[3] Studies have shown that TMI can reduce TBI-related complications, but a lack of robust prospective data and numerous technical obstacles indicate a need for additional surveillance.[4, 5] Today, TMI is not in widespread use even though many treatment centers have the technology to implement it. The goal of this case study is to explore the treatment process (simulation, planning, and treatment) performed by the protocols set in place by Banner MD Anderson in Phoenix, Arizona, to provide the community with a deeper understanding of its benefits.

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Simulation

The patient was positioned supine with legs straight and arms by his side in an SBRT whole-body Vac-Lok (Fig. 1) that was used to ensure daily reproducibility. Special care was taken to mold cradles in the Vac-Lok for the patient's hands. This is a new challenge the simulation team had to face because hand positioning is not relevant for many other treatments. Laser positions on the Vac-Lok were marked and hands and legs were indexed. Abutting the Vac-Lok was a thermoplastic mask that covered the patient from his shoulders to the top of his head. Once the patient was in this position a BB was placed at the level of the pubic symphysis.

The patient was imaged supine, head-first in a Philips Big Bore with a slice thickness of 5 mm. The scan started 3 cm above the head and went as far past the pelvic BB as possible. Because the patient's cranial-to-caudal length exceeded the scanner's range, an additional supine, feet-first scan was acquired by starting 3 cm below the feet and ending as far as possible above the BB. The BB and anatomical landmarks were used to fuse the two scans with RayStation (RaySearch Laboratories, Stockholm, Sweden) treatment planning system (TPS) (Version 11BSP2) to produce a single planning scan. Prior to treatment, a dry run was completed to ensure that all markers were accurately placed.

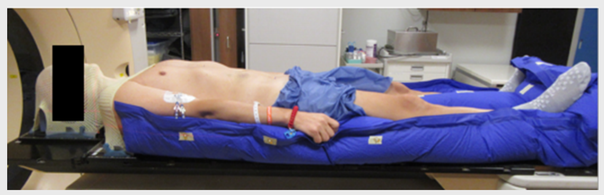

Fig. 1.Patient positioned in Vac-Lok with thermoplastic mask abutting

Planning

The legs were planned first using an AP/PA method. Three isocenters per leg corresponding to the upper, middle, and lower portions of the limb were placed during planning. All isocenters were placed at the same anterior-posterior position midline of each leg. The field sizes varied to meet the needs of the plan. This setup was then duplicated on the contralateral leg.

Five upper-body isocenters were used. The first isocenter was placed 13 cm from the top of the head in a midline location that was determined in the right-left orientation as well as the anterior-posterior direction. The distance of 13 cm was used due to field limitations and the need to flash the superior portion of the brain field. Each upper-body isocenter was advanced 24 cm inferior to the brain isocenter. All upper-body isocenters are shown in Fig. 2 below. Two full arcs were used; one superior and inferior. Each arc's direction alternated between clockwise and counterclockwise as the fields, which were 15 cm wide and overlapped by 2 cm in the center, were treated. Overlapping the fields helped produce homogenous dose distribution in abutting areas. The fifth isocenter was treated with a single full arc for a 14 cm-wide field. Its dose was feathered with the lower-body fields.

The patient's entire bony anatomy and central nervous system plus a 1 cm expansion formed the PTV and was treated to 12 Gy in 8 fractions BID. The goal was for 90% of the PTV to receive 11 Gy. This treatment resulted in 88% coverage at 11 Gy but was accepted due to bony anatomy receiving 91.14% coverage at 11 Gy. The prescription, fractionation, and PTV objectives all fall within standard ranges for TMI treatments planned at other centers. Goals for other critical structures were established as well and are shown in Table 1 below.

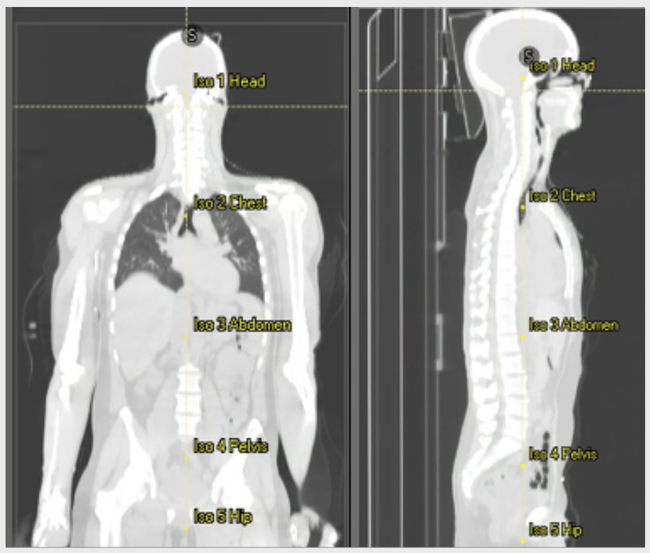

Fig. 2. Coronal and sagittal views of upper-body isocenter alignment.

Priority	ROI/POI	Clinical Objective	Plan Value
1	Kidney Left	At most 700 cGy avg dose	403 cGy
1	Kidney Right	At most 700 cGy avg dose	432 cGy
1	Lung Left	At most 700 cGy avg dose	528 cGy
1	Lung Right	At most 700 cGy avg dose	512 cGy
1	PTV	At least 90% volume at 1100 cGy dose	88.07%
1	PTV	At most 1560 cGy dose at 1.00% volume	1498 cGy
2	Kidney Left	At most 500 cGy avg dose	403 cGy
2	Kidney Right	At most 500 cGy avg dose	432 cGy
2	Lung Left	At most 500 cGy avg dose	528 cGy
2	Lung Right	At most 500 cGy avg dose	512 cGy
2	PTV	At least 90% at volume at 1200	72.31%
2	PTV	At most 1440 cGy dose at 1.00%	1498 cGy
	Bone Total	At least 90% volume at 1100 cGy dose	91.14%

Table 1. Dose Objectives used for TMI compared to actual values

Treatment

TMI treatment averages 3 hours, and the patient's ability to remain completely immobile was a challenge. Patients undergoing this therapy are typically quite ill and may not have the stamina needed to withstand the treatment. Patient education regarding the process is an important aspect of treatment.

On the day of treatment, a physicist was there to help guide the therapists and to place multiple skin dosimeters. The attending physician stopped by briefly to make sure everything was going smoothly and was on standby to answer any questions that arose during treatment.

Treatment began daily with the head and progressed to the feet. The daily setup included taking multiple port films and CBCT images as well as aligning the patient to the brain isocenter, a nearly hour-long process. The process began by matching the head markers on the fitted mask to the wall lasers. Port films were then taken to ensure that the brain isocenter was in position. Following brain isocenter alignment, there was a shift to the pelvis to check the pelvic isocenter accuracy as well as clearance of the machine with respect to the patient's head. Checking gantry clearance is important because, depending on the height of the patient and the machine dimensions, a shift to the pelvis may cause a collision between the patient's head and the machine. Once alignment of brain and pelvic isocenters was completed, a CBCT of the chest and upper abdomen was taken to check for alignment of the lungs and kidneys, then a final shift to the head was done to prepare for treatment's start. All five upper-body isocenters were then treated.

Following upper-body treatment, a 15-minute break was taken to allow the patient to stretch and use the bathroom. The fitted mask was removed for comfort and the patient was then repositioned on the table for the lower body treatment. Lasers were aligned to pelvic markings, and a CBCT was done to make sure alignment to a pelvic isocenter is accurate. This isocenter was used to visualize the inferior part of the pelvis and the knee on the same film. Afterward, treatment began by shifting to each leg isocenter, and the patient was treated with an AP/PA beam. The patient then waited 6 hours before having the upper body treated a second time that day.

CONCLUSIONS

TMI treatment with VMAT is an effective method for sparing critical organs at risk, allowing for potential dose escalation and greater disease control. This technique can be effectively implemented at many clinics across the United States because the necessary infrastructure and technology are already in place. However, VMAT TMI treatment is not commonly used in the United States, possibly because the treatment process is not readily understood. This could be a product of multiple factors such as the rarity of the disease and an extended planning and treatment time.

Once again, TMI is an effective treatment that provides organ-sparing benefits and fewer side effects, but improvements can still be made, especially in aspects of patient comfort. The procedure took three hours, and while our patient was able to stay in the treatment position for an extended period-of-time, he still experienced hand cramping. Other patients with limited mobility and other comorbidities may struggle with these demands. Additionally, a more streamlined approach for setup could be investigated to reduce the patient's time on the table.