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Case Report

Clinical experience of total body irradiation performed on Halcyon™ for a patient diagnosed with acute myeloid leukemia

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ABSTRACT

We aim to publish/document a clinically novel case of total body irradiation (TBI) performed on the Halcyon™. A 21-year-old gentleman diagnosed with high-risk tp53-positive acute myeloid leukemia planned for haploidentical bone marrow transplant post-chemotherapy following which he was declared minimal residual disease, negative was referred for TBI. The patient was placed in the supine position, arms by side with feet together. Immobilization was achieved using a full-body Vac-Lok. Two CT images of the cranial and caudal body parts were acquired. The PTV comprised the whole body minus 3 mm. The prescribed dose was 3 Gy in a single fraction. To achieve the desired dose distribution, we used 15 isocenters. Constraints were given to spare lungs and kidneys. The final plan was evaluated where 90% of the dose is received by 95% of volume, whereas lungs and kidneys received 80% of the prescribed dose, maximum dose of <130% of the prescribed dose is received by 2 cc of whole-body volume. The total time taken for delivering a single fraction is 1 h 15 min. This is the first known reported clinical treatment of TBI on Halcyon machine amidst available medical literature.

Keywords: Total body irradiation, Halcyon™, Isocenter, Dose gradient, Volumetric arc modulated therapy

INTRODUCTION

Total body irradiation (TBI) has been used extensively in bone marrow transplantation as it induces immunosuppression and helps avoid rejection of the donor's marrow. It also helps eradicate cancer cells in not only the same sites where chemotherapy acts but also sanctuary sites such as the brain and testes which are not breached by chemotherapy.[1] TBI is an important part of conditioning regimens for bone marrow transplantation for hematological malignancies such as acute myeloid leukemia, acute lymphoid leukemia, chronic myeloid leukemia, chronic lymphocytic leukemia, multiple myeloma, lymphoma, and other indications.

The traditional method of TBI employed conventional techniques involving larger radiation treatment fields using lung blocks with the patient positioned standing or lying on the side at large distances with an extended SSD. This required larger and more expensive LINAC rooms.[2]

Recently, many centers have initiated the use of CT-based 3D planning with IMRT and inverse planning intending to reduce the dose of OARS and achieve better dose homogeneity. Conformal-

avoidance TBI using either Volumetric Arc Modulated Therapy (VMAT) or Helical Tomotherapy is being used in the Western world albeit with limited clinical experience.[3]

Uehara *et al*. presented the first feasibility study of VMAT with Halcyon™ LINAC for TBI.[4]

We would like to report a case treated for TBI on Halcyon™ machine which is the first clinically reported treatment amidst available medical literature.

Patient selection and clinical case summary

A 21-year-old gentleman, diagnosed with high-risk tp53-positive acute myeloid leukemia, was referred to the Department of Hematology for the treatment and planned for haploidentical bone marrow transplant. He received one cycle of Adriamycin and Cytarabine followed by two cycles of Cytarabine following which he was declared minimal residual disease negative. He was then referred to the Department of Radiation Oncology for TBI before the BMT procedure.

MATERIAL AND METHODS

Halcyon™ (from m/s Varian Medical Systems, USA) is a single energy 6MV flattening filter-free ring-based gantry linear accelerator which has 114 double-layered stacked and staggered MLC with 5 cm/s speed. The maximum field size of 28 × 28 cm^2 with a maximum gantry speed of 4 rotations/min. Our institution is equipped with a Halcyon™ Elite Class LINAC with KVCBCT, MV-MV, and MVCBCT imaging and it has a 5 mm virtual MLC thickness at isocenter. Conventionally, TBI was started using conventional planning by delivering simple AP and PA beams. With the advancement in systems and technology, presently TBI can be done in conventional LINAC using Volumetric Modulated Arc Therapy but in Halcyon™, it comes with its limitations which make it difficult to achieve desired TBI dose distribution.[4]

Immobilization and imaging

The patient was placed in the supine position, arms by side with feet together. The patient was positioned and immobilized on a Vaccum bag (Vaclok, Orfit) with TIMO Headrest type "C." To overcome the roll in patient positioning in daily setup, markings were made throughout the entire length of the vacuum bag and body at the point of intersection and positioned all extremities close to the body and inline as much as possible.

Planning CT scan was acquired on Siemens Biograph™ mCT PET/CT system. Two CT images of the cranial and caudal body parts were acquired. The cranial part was performed using the head-first position ranging from the skull vertex to the upper thigh while the caudal part was acquired in the feet-first position ranging from the toes to the abdomen as the PTV length was much greater than the couch travel limit of Halcyon™. Single CT markers were used in both the image set, in the forehead region for the headfirst image set and the ankle region for the feet first image set.

Contouring and dose prescription

Contouring was performed on the Eclipse Somavision Version 15.6 (Varian Medical Systems Palo Alto, CA, USA). The PTV comprised the whole body minus 3 mm. The organs at risk included the brain, bilateral lens,' bilateral eye globes, heart, liver, lungs, spleen, testis, penile bulb, spinal cord, and kidneys. The prescribed dose was 3 Gy in a single fraction.

Planning

Planning was done on Eclipse (version 15.6) Treatment Planning System from m/s Varian Medical Systems, USA. To achieve the desired dose distribution, we used 15 isocenters of which few have been placed laterally where the width of the patient is more in the thoracic and pelvic region. The junction dose between two CT image sets is controlled by contouring multiple-dose gradient regions on both the CT image sets. Constraints were given to spare lungs and kidneys.

Plan evaluation and treatment delivery

The planning aim was that 90% of the prescription dose is received by 95% of the planning target volume [Figures 1 and 2]. Lungs and kidneys received 80% of the prescribed dose, maximum dose of <130% of the prescribed dose is received by 2 cc of whole-body volume.

Quality assurance of the approved plan was done using portal dosimetry and ArcCheck (m/s Sun Nuclear Corporation, USA) patient-specific QA, both tests were passed. During treatment, *in vivo* dosimetry was done using Gafchromic film, where an average of 7% variation between planned and delivered skin dose is measured.

Kv-CBCT imaging was done for each isocenter and matching was done as necessary before the treatment. The total time taken for delivery of a single fraction is 1 h 15 min.

DISCUSSION

Gruen *et al*. have used a vacuum bag with an adjustable board to provide a steady setup during all treatment processes. In companion, we used the Timo headrest and full body vacuum bag to immobilize the patient, extremities were kept close to the body to minimize the lateral separation and minimize air gaps to achieve homogeneous dose distribution.[5]

Like the feasibility study by Uehara *et al*., which employed 13 isocenters, we used 15 isocenters.[4] We inserted lateral

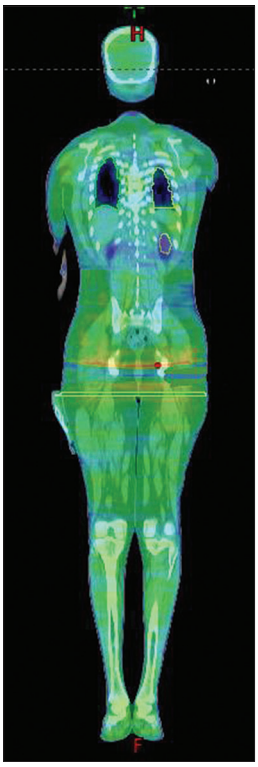

Figure 1: Coronal view.

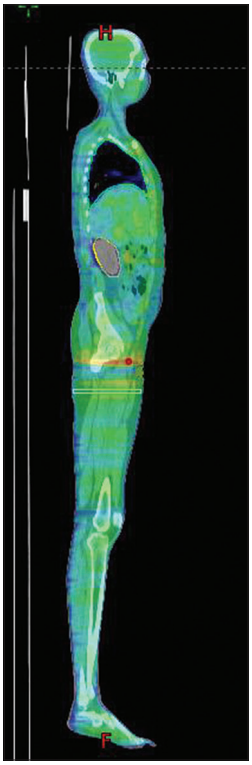

Figure 2: Sagittal view.

isocenters for regions where the lateral separation between isocenters is 10 cm.[6]

While studies by Springer *et al.* where isodose curves have been converted into structures to achieve homogeneous dose distributions; in our study, we have contoured gradient regions injunction of both image sets which provided a greater control while achieving a homogeneous dose distribution.[6]

The planning parameters described in various dosimetric studies describing the feasibility of TBI with Halcyon™ and the first clinical experience of TBI with VMAT were used as benchmarks for plan evaluation. In our study, we were able to achieve the pre-specified parameters of 90% of the prescription dose that should be received by 95% of the planning target volume, and OARs such as the lung and kidney should receive <85% of the prescribed dose.[4,6]

Mancosu *et al.* too employed Gafchromic™ films for *in vivo* dosimetry for multi-isocentric VMAT irradiation of Total Marrow Lymph Nodes and found them to be in good agreement with planned parameters. Using this study as a reference, we used small-sized Gafchromic™ films and placed them at various locations on the body. Recorded values were in good agreement with the calculated values.[7]

CONCLUSION

This is the first known reported clinical treatment of TBI on Halcyon machine amidst available medical literature.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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