VMAT Simultaneous Integrated Total Marrow and Total Body Irradiation (SIMBa)

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INTRODUCTION

Approximately 85% of acute lymphoid and acute myeloid leukemia patients receive total body irradiation (TBI) to suppress the immune system in preparation for a bone marrow transplant (BMT). Additionally, TBI treats "chemotherapy sanctuary sites" including the central nervous system, testes and chemotherapy refractory clonogens of malignant disease. However, TBI has potential, severe complications, including pneumonitis, renal dysfunction, gastrointestinal complications and secondary malignancies. Total marrow irradiation (TMI) has been proposed to reduce toxicities, but studies have shown that sanctuary sites are not adequately treated.

PURPOSE

One proposed method of balancing toxicity with clinical benefit is using two dose volumes, including a higher dose to the marrow and a lower dose to the remaining body tissue to allow for sparing of critical organs at risk. This study demonstrates the dosimetric feasibility of such method using volumetric modulated arc therapy (VMAT) in anticipation of a clinical trial to investigate its usefulness in the conditioning regimen for BMT patients.

METHODS

Twenty patients, previously treated with VMAT-TBI, were re-planned with SIMBA and compared using standard OAR dosimetric indices. PTV_Marrow was contoured using the bone auto segmentation, and PTV_Totalbody was defined as the body-OAR-PTV_Marrow. 12Gy and 8Gy in six fractions were prescribed to the PTV_Marrow and PTV_Totalbody, respectively. The plans were normalized so that 100% of the PTV_Marrow received at least 90% of the dose with the PTV_Totalbody optimized to stay as close to 100% at 90% as possible.

VMAT TBI PLANNING

VMAT-TBI plans were generated using Varian Eclipse™ Version 15.6 treatment planning system. Isocenters were placed along the patient's longitudinal axis starting at the superior portion head with a total of six isocenters being created; Head, Chest, Abdomen, Pelvis, Upper Leg and Lower Leg. Isocenters were placed to ensure a minimum of 5 cm overlap in the AP-defined field size of each field. For the superior four isocenters (Head, Chest, Abdomen and Pelvis) one to three 6 MV photon beam VMAT arcs were used. For the two most inferior isocenters (Upper Leg and Lower Leg) two to three AP- PA fields were utilized. Three PTV targets were created to facilitate planning: PTV_BodyEval, PT_Upper and PTV_Lower. PTV_BodyEval was defined as the Eclipse-defined body contour with a 5mm retraction from the skin minus the entire lung volume and was the primary target. PTV_Upper represented the portion of the PTV_BodyEval that encompassed the VMAT arc isocenters (Head, Chest, Abdomen and Pelvis) and the PTV_Lower represented the portion of the PTV_BodyEval that encompassed the Field in Filed AP/PA technique isocenters ((Upper Leg and Lower Leg)). To create a base dose plan for optimization, the PTV_Lower was planned and calculated first. Then the remaining arc fields, representing PTV_Upper, were simultaneously optimized for coverage and organ sparing.

SIMBA Planning

Using Varian Eclipse™ Version 15.6, two planning target volumes were created: PTV_Marrow and PTV_TotalBody. Remaining consistent with the the TBI planning guidelines, the PTV_BodyEval was defined as the Eclipse-defined body contour with a 5mm retraction from the skin minus the entire lung volume. PTV_Marrow was defined as the entirety of the skeletal system and was consistent with targets found in previous TMI studies. The PTV_Totalbody was defined as the PTV_BodyEval minus the PTV_Marrow and any dose limiting structures/organs at risk. Figure 1 show the target volumes and arc configuration for a representative patient.

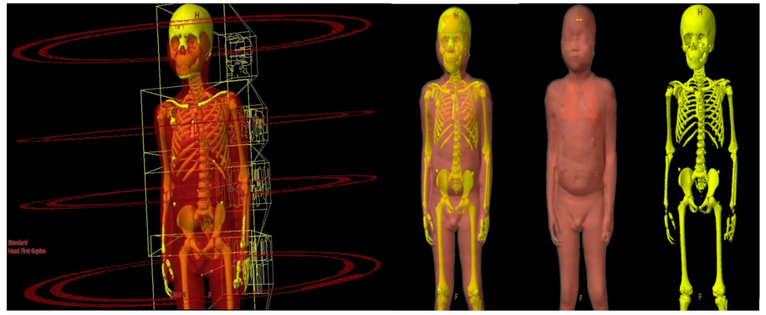

Figure 1: A Representative patient with the planned arc configuration (left) and the representative target volumes (Right).

SIMBA PLANNING OBJECTIVES

The planning aims were to deliver a uniform dose of 12 Gy to at least 90% of the PTV_Marrow and 8 Gy to at least 90% of the PTV_TotalBody while limiting the mean lung dose to less than 8 Gy. The plans were normalized so that 100% of the PTV_Marrow received at least 90% of the dose with the PTV_Totalbody optimized to stay as close to 100% at 90% as possible. Planning and optimization for all fields and isocenters were done simultaneously. Figure 2 shows a representative axial slice of a Traditional TBI (left) and a simultaneous integrated marrow and body approach VMAT TBI (right) prescribed to the same dose with the same color wash visualization. The plans were normalized so that 100% of the PTV_Marrow received at least 90% of the dose with the PTV_Totalbody optimized to stay as close to 100% at 90% as possible.

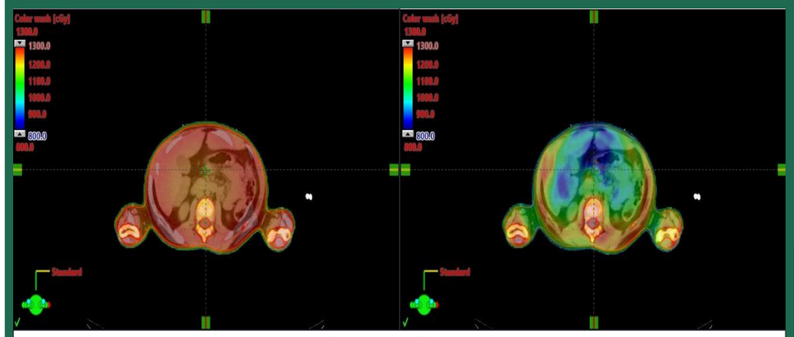

Figure 2: Representative Axial slice of a Traditional TBI (left) and a simultaneous integrated marrow and body approach VMAT TBI (right) prescribed to the same dose with the same color wash visualization. The plans were normalized so that 100% of the PTV_Marrow received at least 90% of the dose with the PTV_TotalBody optimized to stay as close to 100% at 90% as possible.

RESULTS

All twenty patient plans achieved 12Gy/8Gy to at least 90% of the PTV_Marrow and PTV_Totalbody, respectively, with max dose of <16Gy (130%). Table 1 shows the summary of the average mean dose values for selected OARS compared between Traditional TBI and a simultaneous integrated marrow and body approach VMAT TBI. Coverage of the sanctuary sites was maintained despite significant reduction to sensitive OARs.

Table 1: Summary of the average mean dose values for selected OARS compared between Traditional TBI and a simultaneous integrated marrow and body approach VMAT TBI.

	Traditional VMAT TBI	SIMBA VMAT	Difference	
	Average (cGy)	Average (cGy)	Average (%)	σ (%)
Bowel	1108	870	-21.3	4.2
Lung	902	756	-16.3	7.9
Heart	1233	916	-25.3	8.6
Kidney	1191	994	-16.4	6.2
CNS	1270	1225	-2.4	3.2

CONCLUSIONS

This study demonstrates that SIMBA can dosimetrically provide the same PTV/sanctuary site doses as TBI while reducing the doses to OARs. The future clinical trial will interrogate the clinical benefit of these dosimetric balances.

CONTACT INFORMATION

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