Dosimetric Comparison of TBI with a Dedicated Co-60 Irradiator to Tomotherapy-Based TBI and TMLI

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INTRODUCTION

Radiotherapy is one of the most used treatment modalities for different types of cancers. Planning a radiotherapy treatment comes with various challenges. Whatever site is to be treated, the main objective in treatment planning is to give an optimum absorbed dose to the malignant cells while sparing the normal organs at risk (OARs). However, for malignancies involving the entire patient body, like leukemias and lymphomas, achievement of this objective is not so easy. Nevertheless, with the advancements in technology, it has now become much easier to get a targeted and uniform absorbed dose in such cases [1, 2].

Traditionally, the entire body is treated with a uniform radiation dose, sometimes with shielding of some critical organs (i.e. lungs, kidneys etc.), and is known as total body irradiation (TBI) [3, 4]. There exist different approaches for TBI classified into stationary & dynamic TBI techniques. Recently, a better-targeted format of TBI, known as total marrow and total lymphatic irradiation (TMLI), has been proposed [5]. Volumetric modulated arc therapy (VMAT) and helical tomotherapy (HT) has been successfully used for TMLI [6-9].

Despite the special nature of TBI/TMLI, there are only very few dedicated facilities for TBI around the globe. In fact, most of the clinics take the advantage of non-conventional use of commonly available facilities for TBI dose delivery. In our department, we have been using a dedicated Co-60 irradiator (GammaBeam 500 by Best Theratronics, Inc., Kanata, ON, Canada) for TBI since 2016 (the reader is referred to [10] for further details of this technique).

Through this research, we addressed two fundamental questions. Whether it is useful to move on to advanced techniques i.e. tomotherapy or VMAT to deliver TBI/TMLI (instead of Co-60 based TBI)? And if yes, how does the two tomotherapy based treatments, TBI or TMLI, compare to each other? The two questions are addressed by presenting a dosimetric comparison between TBI with dedicated Co-60 irradiator (Gamma-TBI), tomotherapy-based TBI (Tomo-TBI) and TMLI (Tomo-TMLI). In literature, we find no studies on comparing the Gamma-TBI to Tomo-TBI or Tomo-TMLI.

AIM

To present biological and physical dosimetric comparisons between Total Body Irradiation (TBI) with a dedicated Co-60 irradiator (Gamma-TBI), Tomotherapy-based TBI (Tomo-TBI) and Total Marrow & Lymphatic Irradiation (Tomo-TMLI).

METHODS

For Gamma-TBI, a prescribed dose of 12 Gy is delivered in 6-8 AP/PA fractions BID, 1.5-2 Gy/fraction. Cerrobend lung blocks are used to reduce mean lung dose to approximately 9 Gy. For 5 patients treated with Gamma-TBI (1.5 or 2 Gy per fraction [fx] with 2-3 fx as open field and 4-6 fx with lung blocks), comparative Tomo-TBI and Tomo-TMLI plans were generated retrospectively for 12 Gy in 6 fractions BID delivered head-first-supine. The equieffective dose in 2Gy fractions, EQD2 $=D\left({}^{\alpha}/_{\beta}+2\right)/\left(d\left({}^{\alpha}/_{\beta}+2\right)\right)$, was calculated using the concept of generalized equivalent uniform dose, gEUD $=[\sum_{i=1}^{m}(v_i D_i{}^{a})]^{1/a}$, as total dose D. The values for parameter 'a' were taken as 1.2 for lungs, 3.1 for heart, and 1.3 for kidneys. The α/β values of 5 (pneumonitis), 3 (cardiomyopathy) and 2 (nephropathy) were used for lung, heart and kidneys respectively [11, 12].

For Tomo-TMLI, the PTV consisted of bones, lymphatics, brain, spleen, liver, and gonads (PTVTMLI) in contrast the Tomo-TBI PTV (PTV-TBI) included the entire patient body excluding a 1 cm outer rind, lungs, and heart. Since the AP/PA fields for Gamma-TBI were calculated on supine and prone CT scans, respectively, we used the intersection of these two PTVs for target dose comparison between TBI techniques.

RESULTS

The PTV-TBI comparison reveals better prescription dose coverage with Tomo-TBI (V12Gy=76-88%, median doses 12.5Gy-13.0Gy) than with Gamma-TBI (V12Gy=31-61%, median doses 11.6Gy-12.2Gy). Lung dose was significantly reduced with Tomo-TBI (EQD2=4.7Gy±0.3SD) relative to Gamma-TBI (EQD2=7.9Gy±0.5SD). Similarly, EQD2 for heart was reduced from 9.3Gy±0.6SD to 4.1Gy±0.6SD. EQD2 for kidneys was reduced to 3.3Gy±0.3SD for Tomo-TMLI relative to 13.3Gy±0.4SD for Tomo-TBI without kidney-sparing.

With Tomo-TMLI, V12Gy for PTV-TBI (excluding kidneys) ranged from 38-54% (compared to 90% with Tomo-TBI) showing significantly reduced dose to uncontoured normal tissues. Conversely, V12Gy for PTV-TMLI with Tomo-TBI ranged 84-92% (compared to 90% with Tomo-TMLI) indicating greater dose heterogeneity in the Tomo-TBI plan.

Table 1: Comparison of EQD2 doses (calculated from gEUD) for OARs in three techniques

OAR	EQD2±St Dev		
	Gamma-TBI	Tomo-TBI	Tomo-TMLI
Lung	7.9 ± 0.5	4.7 ± 0.3	4.6 ± 0.1
Heart	9.3 ± 0.6	4.1 ± 0.6	4.1 ± 0.3
Kidneys	11.2 ± 0.9	13.3 ± 0.4	3.3 ± 0.3

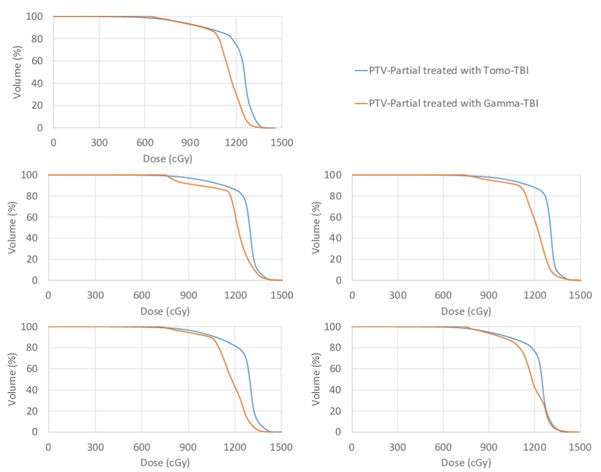

Figure 1: DVH comparison of all 5 patient for PTV-Partial treated with the two TBI techniques

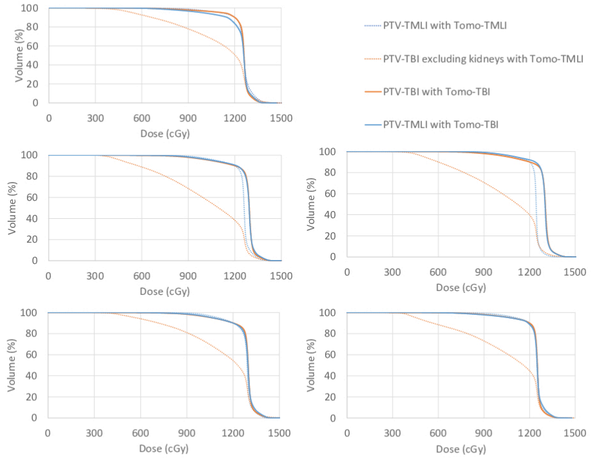

Figure 2: DVH Comparison for all 5 patient for Tomo-TMLI and Tomo-TBI

CONCLUSIONS

Tomotherapy-based TBI can reduce lung and heart EDQ2 to <5 Gy with better target volume coverage than a large-field TBI unit. Tomo-TMLI can provide uniform dose to marrow and lymphatic regions while substantially lowering dose to remaining normal tissues. Both techniques facilitate possible dose escalation without additional toxicity over conventional TBI.

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REFERENCES

1. F. M. K. John P. Gibbons, Paul W. sperduto, "KHAN'S Treatment planning in Radiation Oncology." 2017.
2. F. M. Khan and J. P. Gibbons, Khan's The Physics of Radiation Therapy, 5th ed. 2014.
3. J. Van Dyk, American Institute of Physics., and American Association of Physicists in Medicine., The physical aspects of total and half body photon irradiation. 1986.
4. U. Quast, "Physical treatment planning of total body irradiation: Patient translation and beam zone method," *Med. Phys.*, vol. 12, no. 5, pp. 567–574, 1985.
5. J. Y. Wong, A. Liu, T. Schultheiss, L. Popplewell, A. Stein, J. Rosenthal, et al., "Targeted total marrow irradiation using three-dimensional image-guided tomographic intensity-modulated radiation therapy: an alternative to standard total body irradiation," *Biology of Blood and Marrow Transplantation*, vol. 12, pp. 306-315, 2006.
6. T. Schultheiss, A. Liu, J. Wong, G. Olivera, and J. Kapatoes, "Total marrow and total lymphatic irradiation with helical tomotherapy," *Medical Physics*, vol. 31, p. 1845, 2004.
7. B. Aydogan, M. Yeginer, G. O. Kavak, J. Fan, J. A. Radosevich, and K. Gwe-Ya, "Total marrow irradiation with RapidArc volumetric arc therapy," *International Journal of Radiation Oncology, Biology, Physics*, vol. 81, pp. 592-599, 2011.
8. C. Han, T. E. Schultheisss, and J. Y. Wong, "Dosimetric study of volumetric modulated arc therapy fields for total marrow irradiation," *Radiotherapy and Oncology*, vol. 102, pp. 315-320, 2012.
9. S. K. Hui, J. Kapatoes, J. Fowler, D. Henderson, G. Olivera, R. R. Manon, et al., "Feasibility study of helical tomotherapy for total body or total marrow irradiation," *Medical physics*, vol. 32, pp. 3214-3224, 2005.
10. J. Burmeister, A. Nalichowski, M. Snyder, R. Halford, G. Baran, B. Loughery, et al., "Commissioning of a dedicated commercial Co-60 total body irradiation unit," *Journal of applied clinical medical physics*, 2018.
11. Joiner, Michael C., and Albert J. van der Kogel, eds. *Basic Clinical Radiobiology*. CRC Press, 2018.
12. Warrell, Gregory R., et al. "Organ sparing of linac-based targeted marrow irradiation over total body irradiation." *Journal of Applied Clinical Medical Physics* 20.11 (2019): 69-79.

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