TOTAL BODY IRRADIATION: DOSIMETRIC DATA AND CLINICAL EXPERIENCE USING TOMOTHERAPY

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Abstract— **This study aimed to verify the dosimetric accuracy for TBI patients treated in Helical Tomotherapy (Radixact X9) by deliberately evaluating: (i) TPS planned dose versus reconstructed 3D dose distribution from measured MLC Leaf Open Times in the in-house exit detector using 3Dγ evaluation (2%,2mm); (ii) D_{90} to PTV and D_{50} to OARs of the planned DVH and the reconstructed DVH. To validate the accuracy for the exit detector, point dose measurement was carried out alongside the exit detector approach.**

A total of 5 patients were taken and two sets of CT scans for each patient; one in the Head First Supine (HFS) and Feet First Supine (FFS) position have been obtained. Planning was performed in Accuray Precision treatment planning system (version 3.3.1.3). Prescription was 12 Gy in 6 fractions (2Gy/Fx), each fraction delivered twice for three consecutive days. QA plan was generated in the Cheese phantom and the plan was irradiated with no object on the couch for the exit detector measurement. Point dose measurement was carried out in the same phantom using an Extradin A1Sl cylindrical ion chamber (0.05cc) at three different sites (brain, chest and feet).

For the planning, the average D_{98} of upper (HFS) and lower (FFS) PTV were 94.52±2.4% and 96.48±2.4% respectively. And the average V_{95} of upper and lower PTV were 94.02±3.18% and 98.78±1.02 respectively. The exit detector gave an excellent 3Dγ pass rate of 100% for 2%, 2mm and the D_{90} for PTV and D_{50} for OARs from reconstructed DVH yielded a result within ±3% when compared with the planned DVH for all patients. Point dose measurements were within ±3% for all sites.

The close agreement between the exit detector and the point dose measurement, validated the accuracy and reliability of LOTS reconstruction method as a pre-treatment verification.

Keywords— **Total body irradiation, Helical tomotherapy, Exit detector.**

I. INTRODUCTION

Total body irradiation (TBI) is a special radiotherapeutic approach that provides to a patient's whole body a uniform dose to within ±10% of the prescribed dose based on IAEA acceptation [1,2] - far greater than would be accepted for standard radiotherapy techniques (within +7% and -5%) [3]. Megavoltage photon beams, either ^{60}Co γ-rays or megavoltage X-rays, are used for this motive.

A preferred dose for TBI as a myeloablative regimen, 200 centigray (cGy) two times daily (bid) for three consecutive days with a total radiation dose of 1,200 cGy, has been performed since 1997 as part of bone marrow transplantation program [8-11].

The upward thrust of IMRT-based TBI, which include HT help reduce detrimental complications by increased dose control over OARs. The OARs exposed in TBI, in contrast to usual cancer treatment, is extensively greater, consisting of lungs, liver, heart, kidneys and bladder. So minimal dose to these regions is paramount [4]. TBI is an obvious candidate for delivery with the Tomotherapy machine.

Tomotherapy is a unique machine to deliver IMRT and has the benefit that the beam travels helically along the axis of the patient, with multi-leaf collimators (MLCs) offering dose sculpting. The MLCs modulate the beam intensity over the PTV of interest, which can provide a large dose gradient around OARs [5, 6]. Treatment planning system (TPS) software is used for dose calculation and optimisation.

Helical tomotherapy is a treatment choice that offers MVCT-based image guidance and intensity-modulated radiotherapy using a fan beam of radiation. Performing a MVCT before the treatment improves the accuracy of the treatment delivery. With tomotherapy, a new capability exists to conform the dose to very specific areas of the body and it is possible to target the specific parts of the patient's anatomy, in principle with the bone marrow, while sparing sensitive tissues such as the lung. By providing a 360◦ continuous, yet controlled exposure of the PTV, HT's unique delivery enables a larger field exposure at nominal treatment distance in contrast to conventional linac-based IMRT. HT can potentially offer less radiation-induced toxicity to surrounding OARs.

II. MATERIALS AND METHODS

A. Patients

Data from all patients that underwent TBI between 2021 and 2024, in our institute had been analysed. A total of 5 patients had been analysed (Table 1). TMLI patients were excluded considering the fact that it is far out of topic for this study. All patients were immobilised in supine position. TBI treatment at our institution involved a total dose of 12 Gy delivered in 2 daily fractions of 2 Gy over 3 days.

Table 1 Patients treated with TBI between 2021-2024

Patient No.	Sex/ Age (years)	Diagnosis
1	Male (17)	Leukaemia
2	Female (19)	B – ALL
3	Male (23)	ALL
4	Male (43)	B – NHL
5	Male (22)	B – All

B. Treatment Unit

Radixact X9 Tomotherapy takes the shape of an RT device with a linear accelerator mounted on a slip-ring construction, much like a CT device however with a much higher energy and dose rate. It uses an IMRT technique in which the patient is treated slice by slice by IMBs in a way analogous to CT imaging. A unique collimator is designed to generate the IMBs as the gantry rotates around the longitudinal axis of the patient. These days, helical tomotherapy permits the couch to translate constantly with the rotating fan beam, akin to helical CT, administering a helical treatment pattern to the patient. The linac has a maximum energy of 6 MV, with Flattening Filter Free (FFF) delivery of IMRT with increased dose rate of 1000 MU/min. Daily imaging is acquired using the treatment beam at lower energy 3.5 (MeV), so the imaging and treatment isocenters coincide.

The gantry rotation period is 1-5 rotations per minute (RPM). MLC on a Tomotherapy device is driven by pneumatic controllers and has 64 interlacing leaves, made of tungsten and the leaves are interlaced (tongue and groove design) arranged in banks of 32 leaves each. The MLC provides the intensity modulation during treatment. The width of the MLC at the isocentre is 0.625 cm, and the linac target to-isocentre distance is 85 cm. The pneumatic drivers enable the MLC to open or close the leaves in 12-17 milliseconds. This technical gain of the MLC and the helical delivery pattern allows excessive delivery modulation.

Opposite to the linac is an MVCT detector for imaging and QA purposes, i.e., a 640-channel xenon-filled tungsten septal-plate detector with a field of view (FOV) of 39.4 cm. The gantry rotation speed is 11.8–60 secs per revolution and the leaves are binary; they are always programmed to be open or closed. The total opening time per optimisation angle is called the leaf open time (LOT) and is usually presented as a leaf open time histogram (LOTH).

The MVCT imaging system of the Tomotherapy system is used for the treatment position verification of the patients. The on board detector similarly may be used for delivery verification without the patient on the couch. The reconstruction of three-dimensional doses on HT using exit dose measurement via the in-line CT detector array is feasible.

C. CT Simulation

The CT images of the lower and upper region of the phantom with a slice thickness of 3 mm were acquired using SOMATOM confidence CT (Philips Medical Systems, Cleveland, OH, USA). Due to the limitation of helical tomotherapy to a length of 135 cm, two sets of CT scans of 5 mm slice thickness were acquired for legs and corpus separately. First scan was from vertex to mid-thigh in the head first supine (HFS) position, and the second scan from toes to the upper thigh in the feet first supine position (FFS) by means of rotating the patient to 180°. Patients were immobilized in the course of CT scans acquisitions using a head support with a five clamps immobilizing mask covering the head and the thorax, as well as a mask positioned on the thighs secured to a carbon fiber plate (Orfit Industries, Vosveld, Belgium). External feet rotations blocking was achieved using a specific ankles baseplate system. Reference fiducial markers had been located at three different positions in planning CT scans. In the first CT scan labelled as HFS, two reference markers are positioned at the head region and mid-chest level and second CT scan labelled as FFS, a third marker is positioned at the mid-thigh knee plane to create junction for planning. These fiducial markers then assists in the positioning of the lasers and the field junction position on the thighs during treatment. Verification and alignment of all three fiducials in axial planes were done on CT couch at the time of CT simulation. The CT datasets were then transferred to the Tomotherapy treatment planning system (Precision, Accuray, v 3.3.1.3) for contouring.

D. Contouring

After importing CT scan images, two treatment plans were created: HF (Head First) for the upper body and FF (Feet First) for the lower body.

PTVs and critical organs were outlined for each slice. PTV consists of the whole body excluding the OARs; larynx, lungs, heart, kidneys, liver, eyes, lens and the anal canal**.** The junction in the thigh region in HFS was divided into five target volumes of 2 cm thickness and are named as 1PTV, 2PTV, 3PTV, 4PTV & 5PTV from top to bottom to receive 10 Gy, 8 Gy, 6 Gy, 4 Gy and 2 Gy of dose respectively. FFS is also divided into PTV (Lower) & five target volumes of 2 cm thickness and are named as 5PTV, 4PTV, 3PTV, 2PTV and 1PTV from top to bottom to receive 10 Gy, 8 Gy, 6 Gy, 4 Gy and 2 Gy of dose respectively.

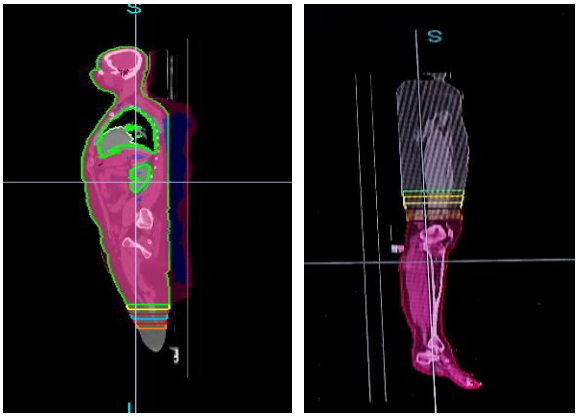

Figure 1: Feet-first supine plan (left); Head-first supine plan (right)

E. Planning and Dose Prescription

A helical tomotherapy treatment plan for TBI was generated for the patient images and contours. The prescription 12 Gy, 2 Gy/fx, 6 fractions was used for planning to cover PTV with 90% of the total dose.

Table 3: Treatment plan parameters used

Patient	Treatment Plan Parameters		
	Field width (cm)	Pitch	Modulation factor
1	5	0.40	3.00
2	5	0.30	3.00
3	5	0.30	3.00
4	5	0.30	3.00
5	5	0.29	2.60

The tomotherapy Accuray Precision treatment planning system version 3.3.1.3 carried out the dose calculation and optimisation for the imported contouring information. Field width was set to 5 cm and dynamic jaw mode was used. Each 2 Gy fraction was delivered twice a day for three consecutive days, with a minimum of six hours between the two daily fractions. Main dose constraints for organs at TPS were mean lung doses of less than 7.5 Gy to decrease the risk of lung complications, and mean kidney doses of 10 Gy. The general method for dose optimisation involved controlling the dose to the lungs and the kidneys, at the same time having maximum coverage to the PTV and the CTV. The upper and lower part of the body was planned separately and united in MIM software version 7.1.90 (MIM Software, Inc.) to control hot and cold spots in intersecting areas.

F. Patient Specific QA

With the intention to ensure agreement in between the delivered radiation with calculation, the patient quality assurance (QA) was accomplished before each patient treatment, required to assure patient safety and to validate every treatment plan. Two methods were performed as a patient specific quality assurance. The first is the point dose measurement carried out using 0.05 cc Extradin A1SL cylindrical ionisation (Standard Imaging, Inc. Middleton, WI) and the second, by using the in-build MVCT detector.

G. Delivery Analysis Using In-House Exit Dosimetry Tool

The Delivery Analysis software operates on a stand-alone workstation separate from the treatment system network and can process input data from multiple machines. The Delivery Analysis receives all data via direct connection to the treatment system database. The pre-treatment QA in Delivery Analysis software makes use of the on-board detector data to infer the MLC leaf open times. The leaf open times, along with beam parameters inclusive of the transverse profile shape, determine the delivery fluence. Prior to pre-treatment QA, a QA plan of the phantom was created. Then the plan is delivered on the machine. The treatment plan is irradiated with no object on the couch. The MVCT detector recorded transmitted radiation from the carbon-fiber Tomo couch were used to reconstruct the MLC-LOTS, which subsequently was used to reconstruct the 3D dose distribution on the CT datasets of the patient. The ensuing dose distribution is compared and analysed to the planned dose distribution using 3D gamma analysis and planned versus reconstructed 3D dose distribution using standard dose-volume histogram (DVH). The gamma acceptance criteria of 2%2mm were used for 3D-γ analysis.

H. Treatment Delivery

TBI was delivered with the head first to the thigh region junction, and the patient was later rotated and put in with the toes towards the gantry position and radiation was delivered from the toes to the thigh region junction to complete the TBI procedure. Pre-treatment imaging and treatment delivery were divided as the patient was treated in both HFS and FFS positions. Treatment was interrupted each time after a pre-specified time for image verification. In HFS treatment, the first MVCT scan was obtained from lower neck to upper abdomen level and the second MVCT was acquired from the vertex to the mid-chest level. After applying the necessary lateral and vertical corrections, patient was treated up to the upper abdomen. The third MVCT scan was obtained covering the entire abdomen up to mid-thigh, the position of scrotum was verified, and the rest of the patient treatment was completed for HFS plan. Next, the patient was rotated by 180° (in yaw plane) with

the same immobilization and alignment in place for FFS treatment plan. The fourth MVCT was acquired in the ankle and couch corrections were applied (including the longitudinal corrections since the patient was moved manually) and treatment was delivered with FFS plan.

III. RESULTS

A. Planning

We evaluated the dose received by 98% of the volume of the target (D_{98}) and volume covering 95% of the dose (V_{95}) for both upper PTV and lower PTV regions and the mean dose (D_{mean}) for OARs from the dose–volume histogram (DVH) report of each plan.

D_{98}- The average D_{98} doses of PTV (upper) and PTV (lower) were 94.52± 2.4% and 96.48± 2.4%

V_{95} – The average V_{95} doses of PTV (upper) and PTV (lower) were 94.02±3.18% and 98.78 ± 1.02%

The D_{mean} values for OARs were taken into account and the data is shown in Table 4.

Homogeneity index- The homogeneity index is another important quality indicator, which indicates the degree of uniformity of dose within target (Table 3).

Table 3: Homogeneity Index for PTV

Patient No.	HI	
	Upper PTV	Lower PTV
P1	1.17	1.06
P2	1.62	1.13
P3	1.60	1.25
P4	1.49	1.18
P5	1.48	1.18

HI = maximum dose/ prescribed dose

$$= \frac{Dmax\ (100\%)}{Rx\ dose}$$

In a perfectly homogeneous case, 100% of the structure gets 100% of the dose (HI=1.0).

Table 4: D_{mean} values for OARs

Structure	$D_{mean\%}$ (Gy)				
	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Lung (L)	7.38	6.98	7.59	7.68	7.40
Lung (R)	7.57	6.92	7.05	7.75	7.19
Kidney (L)	5.40	8.79	7.11	9.77	6.48
Kidney (R)	5.04	8.64	6.81	10.34	5.76
Liver	6.39	9.09	7.52	9.93	7.35
Heart	6.43	8.05	7.39	9.54	6.35
Lens (L)	2.37	2.84	1.80	2.20	1.56
Lens (R)	2.63	2.89	1.96	2.25	1.50
Eye (L)	6.19	5.58	3.53	2.93	2.02
Eye (R)	6.42	5.72	3.30	3.00	2.02
Larynx	4.34	12.21	8.25	8.25	11.65

B. Pre-Treatment Verification

In the in-house exit detector tool, two types of results were analysed with exit detector tool which includes 3D gamma and D_{90} and D_{50} values for PTV (upper and lower) and OARs respectively from DVH reconstruction.

DVH reconstruction - The DVH reconstruction allows direct comparison between the planned and measured doses across the PTV and OAR sub-volumes. This is shown in Figure 2.

3D Gamma - Good agreement was observed between planned and reconstructed 3D dose distribution having dose difference not more than 2% at 2 mm in upper body plan as represented by isogamma levels. No isogamma levels above 1 were seen for all patients except one which is shown in Figure 3.

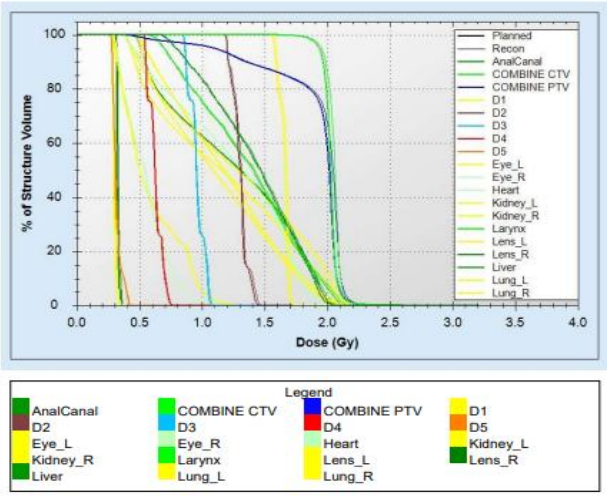

Figure 2: Planned and reconstructed cumulative DVH for various sites in the upper body plan. Planned dose profile in bold line and reconstructed dose profile in thinner line.

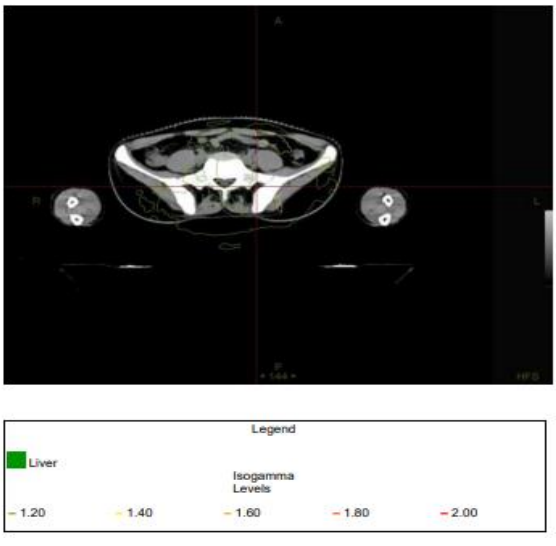

Figure 3: Iso-gamma level seen greater than one for patient 3

The overall dosimetric results evaluated are given below. The difference is presented as mean ± standard deviation (from five clinical plans).

The 3D gamma pass rate, using 2%/2mm criteria determined by exit dosimetry tool were all 100%. No uncertainties were present as the measurement was conducted once.

Table 5: 3Dγ values of 2%/2mm for various sites

Site	3Dγ values from comparison of planned and reconstructed dose distributions in various sites				
	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Upper body PTV	100%	100%	100%	100%	100%
Lower body PTV	100%	100%	100%	100%	100%
Lungs (L)	100%	100%	100%	100%	100%
Lungs (R)	100%	100%	100%	100%	100%

The ionisation chamber measurements were within ±5% for all sites (Table 6)

C. Overall Dosimetric Evaluation

The overall dosimetric results evaluated are given below. The difference is presented as mean ± standard deviation (from five clinical plans)

Table 6: Overall dosimetric results

Dosimeter	Dose and other metrics used	Result
Ionisation chamber	% dose difference	PTV brain: -0.89 ± 1.78% PTV chest: -1.83 ± 1.84% PTV lower limb 0.35 ± 2.6%
Exit dosimetry	D_{90} dose difference	Upper PTV: 0.72 ± 0.13% Lower PTV: 0.99 ± 0.62%
	D_{50} % dose difference	Lung (L): 0.99 ± 0.17% Lung (R): 0.94 ± 0.15% Liver: 0.72 ± 0.21 % Kidney (L): 0.81 ± 0.35% Kidney (R): 0.70 ± 0.37% Eyes (L): 0.65 ± 0.51% Eyes (R): 0.43 ± 0.61%
		Upper PTV: 100% Lower PTV: 100% Lung (L): 100% Lung (R): 100%

IV. DISCUSSION

The specialized HT delivery method is commonly used for treating lengthy or large areas like total body irradiation. The main intention of this study was to deliver TBI using helical tomotherapy. Despite the fact that it is simple in contrast to conventional treatments, HT TBI is a time-consuming process and is particularly tough to manage in the context of other indications. As helical tomotherapy is limited to a maximum treatment length of 135 cm, patients taller than 135 cm require two planning computed tomography (CT) scans to fully cover the body.

The planned-measured dose disagreements across PTV and OAR sites were within the recommended 5% set by ICRU [46, 4], as proven in table 6 using ionisation chambers and exit dosimetry. The in-house exit dosimetry tool yielded a 3D gamma pass rate, using the 2mm/2% criteria of 100%. The high pass rate is due to the absence of set-up errors from phantom positioning. However, a few regions of the PTV, those of which did not meet the criteria of 2%/2mm tolerance having gamma values greater than 1 have also been observed (Figure 3). A likely reason for this dose discrepancy is the presence of a non-uniform dose region and also as a result of balancing among PTV to acquire 12 Gy while additionally minimising exposure of radiation to vital organs. The good agreement both in absolute dose and 3Dγ of less than 5% between ion chamber and exit detector measurement, in all patients confirmed the accuracy and reliability of LOTS reconstructed method in Delivery Analysis against the standard methods. 3Dγ was 100% for all plans and PTVs even after tightening the calculation standards to 2%/2mm.

This study shows that helical tomotherapy can effectively decrease the radiation dose to crucial organs, like the lungs, without the need of extra measures including external blocks or compensators required for shielding each individual organ. The dose to the lungs was reduced, while still maintaining full dose coverage in areas like ribs and sternum that can be affected with traditional methods.

TBI plans couldn't be established using the ArcCHECK dosimeter because of limited experience of using ArcCheck for long targets. Nevertheless, the Exit detector DQA tool provided a valuable solution for accurate treatment verification in such cases. The advantage of exit detector DQA is that, if machine delivery errors result in dose errors beyond the measurement surface, those phantom-based QA techniques won't be capable to detect them. The OBD has higher resolution than external planar or cylindrical detectors arrays, taking into consideration the increased detection sensitivity to MLC errors. However the exit detector DQA tool focuses specifically on MLC movements and their effects on patient dose, so there will be numerous other mechanisms for plan delivery failure which could be studied in the near future. Additionally, the reconstruction method in Delivery Analysis does not test for differences in couch position, or treatment field position. Only variations in MLC-LOT are considered when calculating dose differences and the reconstructed 3D dose calculation assumes that there is no change in the patient anatomy and tumour geometry.

V. CONCLUSION

The use of an in-house exit dosimeter as a dosimetric verification system permit the DQA analysis to be made in three-dimensional (3D). Therefore, users can evaluate the dose distribution between the measurement and calculation in more detail compared with the phantom based QA methods. TBI with helical tomotherapy although takes a lot of effort away, it can be concluded that it is one of the efficient methods to treat TBI due to its higher dose homogeneity and hence sparing of critical organs.

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VI. REFERENCES

1. F. M. Khan, The Physics of Radiation Therapy (Lippincott Williams & Wilkins, Philadelphia, 2010), pp. 405–412.
2. E. B. Podgorsak, "Special procedures and techniques in radiotherapy," Radiation Oncology Physics: A Handbook for Teachers and Students (IAEA, Vienna, 2005), pp. 505
3. International Commission on Radiation Units and Measurements, "Prescribing, recording and reporting photon beam therapy," Report No. 50 (ICRU, Bethesda, MD, 1993)
4. Shueng PW, Lin SC, Chong NS, Lee HY, Tien HJ, Wu LJ, et al. Total marrow irradiation with helical tomotherapy for bone marrow transplantation of multiple myeloma: first experience in Asia. Technology in cancer research & treatment. 2009;8(1):29–37.
5. Yawichai K, Chitapanarux I, Wanwilairat S. Helical tomotherapy optimized planning parameters for nasopharyngeal cancer. In: Journal of Physics: Conference Series. vol. 694. IOP Publishing; 2016. p. 012002.
6. Sevillano D, M´inguez C, S´anchez A, S´anchez-Reyes A. Measurement and correction of leaf open times in helical tomotherapy. Medical physics. 2012;39(11):6972–6980
7. AAPM. The physical aspects of total and half body photon irradiation; 1986.
8. Wolden S. et al. Am J Clin Oncol: American College of Radiology (ACR) and American Society for Radiation Oncology (ASTRO) practice guideline for the performance of total body irradiation 2013
9. Storb R, Raff RF, Appelbaum FR, Deeg HJ, Graham TC, Schuening FG, et al. Fractionated versus singledose total body irradiation at low and high dose rates to condition canine littermates for DLA-identical marrow grafts. Blood 1994;83(11):3384–9.
10. CorvÓ, R.; Lamparelli, T.; Bruno, B.; et al. Low-dose fractionated total body irradiation (TBI) adversely affects prognosis of patients with leukemia receiving an HLA matched allogeneic bone marrow transplant from an unrelated donor (UD-BMT). Bone Marrow Transplant. 30:717–23; 2002.
11. Quast U, et al. Whole body radiotherapy: A TBI-guideline. Journal of Medical Physics. 2006;31(1):5.
12. Rajesh Thiyagarajan1, Dayananda Shamurailatpam Sharma1 , Suryakant Kaushik , Mayur Sawant , K. Ganapathy , N. Arunai Nambi Raj , Srinivas Chilukuri , Sham C. Sundar , Kartikeswar Ch. Patro , Arjunan Manikandan , M. P. Noufal , Rangasamy Sivaraman , Jose Easow and Rakesh Jalali "Leaf open time sinogram (LOTS): a novel approach for patient specifc quality assurance of total marrow irradiation"
13. Kazuo Tarutani1, Masao Tanooka1, Keisuke Sano, Okada Wataru, Masayuki Fujiwara1, Koichiro Yamakado "Evaluation of Delivery Analysis to Detect Intrafractional Motion during Tomotherapy".
14. Gökçe Uçar Alveroğlu, İnci Kingir Çeltik, Canan Köksal Akbaş, Hatice Bilge Becerir "Dosimetric Evaluation of Total Body Irradiations with Helical Tomotherapy: Phantom Study".
15. W.H. Leer, J.J. Broersel, H. De Vroomel, A. Chinl, E.M. Noordijkl and A. Dutreixz "Techniques applied for total body irradiation".
16. Carson Wills, BS; Sheen Cherian, MD; Jacob Yousef, BS; Kelin Wang, PhD; Heath B. Mackley, MD, FACRO, "Total body irradiation: A practical review".
17. D. Sevillano, C. Mínguez, A. Sánchez, and A. Sánchez-Reyes, "Measurement and correction of leaf open times in helical tomotherapy," Medical Physics.
18. V. Althof B. De Ost N. Reynaert K. Schubert E. Sterpin J.B. van de Kamer, "Quality Assurance for Tomotherapy Systems", Report 27 of the Netherlands Commission on Radiation Dosimetry.
19. R. Suna, X. Cuencaa , R. Itti , S. Nguyen Quocc , J.-P. Vernant , J.-J. Mazerona , C. Jenny , M. Chea, "First French experiences of total body irradiations using helical TomoTherapy®".
20. Deshpande S, Xing A, Metcalfe P, Holloway L, Vial P, Geurts M. Clinical implementation of an exit detector-based dose reconstruction tool for helical tomotherapy delivery quality assurance. Med Phys
21. Haraldsson A, Engellau J, Lenhof S, Engelholm S, Bäck S, Engström P. Implementing safe and robust Total Marrow Irradiation using Helical Tomotherapy—a practical guide. Phys Med.
22. M. Alber, B. Mijnheer, and D. Georg, Guidelines for the verification of IMRT. Estro Brussels, Belgium, 2008.
23. Low DA, Dempsey JF. Evaluation of the gamma dose distribution comparison method. Med Phys. 2003; 30:2455–2464.
24. Mackie TR, Holmes T, Swerdloff S, Reckwerdt P, Deasy JO, Yang J, et al. Tomotherapy: a new concept for the delivery of dynamic conformal radiotherapy. Medical physics. 1993;20(6):1709–1719.
25. Barrett A. Total body irradiation. Reports of Practical Oncology & Radiotherapy. 1999;4(3):47–64.
26. Quast U. Total body irradiation - review of treatment techniques in Europe. Radiotherapy and Oncology. 1987;9(2):91–106.

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