

Evaluation of Surface Dose and Commissioning of Compensator-Based Total Body Irradiation

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Abstract

Purpose: The aim of the current study is to commission compensator-based total body irradiation (TBI) and to compare surface dose using percentage depth dose (PDD) while varying the distance between beam spoiler and phantom surface. **Materials and Methods:** TBI commissioning was performed on Elekta Synergy® Platform linear accelerator for bilateral extended source to surface distance treatment technique. The PDD was measured by varying the distance (10 cm, 20 cm, 30 cm, and 40 cm) between the beam spoiler and the phantom surface. Beam profile and half-value layer (HVL) measurement were carried out using the FC65 ion-chamber. Quality assurance (QA) was performed using an in-house rice-flour phantom (RFP). *In-vivo* diodes (IVD) were placed on the RFP at various regions to measure the delivered dose, and it was compared to the calculated dose. **Results:** An increase in Dmax and surface dose was observed when beam spoiler was moved away from the phantom surface. The flatness and symmetry of the beam profile were calculated. The HVL of Perspex and aluminum is 17 cm and 8 cm, respectively. The calculated dose of each region was compared to the measured dose on the RFP with IVD, and the findings showed that the variation was <4.7% for both Perspex and Aluminum compensators. **Conclusion:** The commissioning of the compensator-based TBI technique was performed and its QA measurements were carried out. The Mayneord factor corrected PDD and measured PDD values were compared. The results are well within the clinical tolerance limit. This study concludes that 10 cm –20 cm is the optimal distance from the beam spoiler to phantom surface to achieve prescribed dose to the skin.

Keywords: Beam spoiler distance, compensator-based total body irradiation, surface dose analysis, total body irradiation

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INTRODUCTION

Total body irradiation (TBI) is a specialized Magna field radiation therapy technique used in the treatment protocol of certain specific malignancies. It is an essential part of the myeloablative conditioning regime before hematopoietic stem cell transplant used in the treatment of acute leukemias such as acute myeloid leukemia (AML) and acute lymphoid leukemia (ALL).^[1] The advantage of TBI over other conditioning regimens is that no tumor cell being harbored in sanctuary sites such as the central nervous system/testis will be spared.^[2] Its efficiency does not depend on blood supply and is not affected by variable drug absorption, distribution, and metabolism. TBI is also used in reduced-intensity conditioning regimens for immune modulation to enable successful engraftment and suppress graft rejection.^[2] The complications associated with TBI include nausea, vomiting, loss of appetite, diarrhea, mucositis, headache, fatigue, parotitis, pneumonitis,

infertility, second malignancy, cardiovascular diseases, cataract, leading deficits, and growth failure in children.

The aim of TBI is to achieve a whole-body uniform dose within $\pm 10\%$ of the prescribed dose. To achieve a whole-body uniform dose, different techniques are used in different institutions for treating stem cell transplant patients. The different TBI techniques include moving table technique, dynamic field matching, step translation, gravity oriented compensator, volumetric-modulated arc therapy, and field in field techniques with computed tomography (CT) images.^[3-7] Considering the large target

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volume, extended source to surface distance (SSD) between 350 cm to 400 cm is needed to achieve uniform dose distribution in a whole patient body. *In vivo* dosimetry is mandatory for the treatment of TBI patients to monitor the dose received by various regions in the body.^[8-10] Whenever SSD is increased, the dose rate will reduce according to the inverse square law. The treatment time will be high with extended SSD treatment. Most of the centers commonly use standing position AP/PA (anterior to posterior/posterior to anterior) or lying supine position bilateral extended SSD treatment technique for treating TBI patients. In the standing treatment position, patient is less comfortable compared to the lying supine position. To measure the distance from isocenter to patient surface like isocenter to umbilicus, ear, knee, and ankle will be easier with SSD technique. For bilateral TBI technique, using SSD technique will be more accurate while patient positioning and placing the compensator in the appropriate places. For SSD treatment technique we need to take percentage depth dose (PDD) measurement. A disadvantage of treating bilateral technique is dose inhomogeneity due to varying thickness of each region of the patient body. To overcome dose inhomogeneity, compensators were introduced at appropriate places. In the bilateral and AP/PA treatment technique, the skin-sparing effect will be seen in the dose build-up region. To overcome the skin-sparing effect (i.e., to achieve enough skin doses) beam spoiler (acrylic sheet) is introduced between the patient and the treatment machine. Commissioning of TBI procedure is an essential step before treating the patient; different studies were conducted for different TBI commissioning techniques. The commissioning of different techniques such as dedicated cobalt 60 unit for TBI, 3D arc-based TBI, and bilateral techniques with plastic bags were performed by different institutions.^[11-13]

The present study evaluates the skin dose while changing the beam spoiler distance from the phantom surface. Furthermore, it explains the commissioning and validation of compensator-based TBI.

MATERIALS AND METHODS

Measurement setup

Elekta Synergy Platform™ linear accelerator was used for TBI commissioning and treatment. The gantry angle, collimator angle, field size, and photon energy were set at 270°, 45°, 40 × 40 cm² and 6 MV, respectively. The phantom was placed on a motorized treatment couch at an extended SSD of 385 cm from the source. A beam spoiler which is made up of acrylic sheet of 1 cm thickness was introduced between phantom and source.

Percentage depth dose measurement

The PDD was measured with the beam spoiler kept at a 10 cm distance from the phantom surface. The measurement was carried out using acrylic phantom of size 30 × 30 × 30 cm³ and two chambers – Parallel plate ion chamber (PPC40) and FC65 cylindrical ion chamber. PPC40 was used in the build-up region for depths ranging from 0.1 cm to 1.5 cm, and the FC65

ion chamber was used for the depths ranging from 1.0 cm to 24.0 cm. The same PDD measurement setup was carried out for 20 cm, 30 cm, and 40 cm beam spoiler distance from the phantom surface.

$$PDD = \frac{\text{Dose at any depth}}{\text{Dose at } D_{max}} \times 100\% \quad (1)$$

Beam profile measurement

The cross-line beam profile was measured using acrylic phantom of size 30 × 30 × 30 cm³, and FC 65 ion chamber kept at 10 cm depth. During profile measurement, the beam spoiler was kept at a distance of 20 cm from the phantom surface. From the beam's central axis (CAX), the phantom, along with the chamber, was moved in a straight line with a step size of 5 cm till 120 cm toward the left side. Similarly, the beam profile was measured toward the right side of the beam with a step size of 5 cm. The flatness and symmetry were analyzed using the following formula:

As per the International Electrotechnical Commission protocol, the flatness and symmetry were defined as:^[14]

$$\text{Flatness (\%)} = \frac{D_{max}}{D_{min}} \times 100\% \quad (2)$$

Where D_{max} represents maximum dose in the beam profile; D_{min} represents minimum dose in the beam profile;

The symmetry of the beam profile is defined as the maximum dose ratio of two symmetrical points of the beam.

$$\text{Symmetry (\%)} = \left(\frac{D(x, y)}{D(-x, -y)} \right)_{\text{Max}} \times 100\% \quad (3)$$

Where, D (x, y) and D (-x, -y) represents two symmetrical point of maximum dose on the beam profile.

Half-value layer measurement

HVL was measured using 30 × 30 × 30 cm³ acrylic phantom with beam spoiler at 20 cm distance from the phantom surface and FC 65 ion chamber at 5 cm depth in the beam's CAX. Initially, 100 monitor units (MUs) were delivered without any compensator material, and the dose was calculated for the open field in the CAX. After the initial open field measurement, a Perspex compensator of 1 cm thickness was placed in the path of the beam along its CAX. The thickness of the compensator was increased until the dose became half of its initial value. The same procedure was followed for the aluminum compensator.

Treatment monitor units and compensator calculation

The prescribed MU at the mid-plane of the patients is calculated from the following equation,

$$\text{Treatment MU} = \frac{\text{Tumor Dose / Side}}{\text{Output} \times \text{PDD of the Umbilicus}} \quad (4)$$

where,

Tumor dose is the prescription dose per side,

Output is the dose in cGy/MU at D_{max} depth for 40 × 40 cm² field size with beam spoiler distance at 20 cm depth,

PDD is the PDD at the umbilicus depth.

The thickness (T) required for Perspex compensator for different region was calculated using the following formula:

From the exponential equation,^[15]

$$I = I_0 \times e^{-\mu t} \tag{5}$$

$$\mu = \frac{0.693}{HVL} \tag{6}$$

where, HVL for Perspex material was measured to be 17 cm

$$T = \ln \frac{I}{I_0} \times 24.53 \text{ cm}$$

Perspex compensator thickness (T)

$$= 24.53 \times \ln \frac{\text{Midplane dose of the region}}{\text{Midplane dose of the umbilicus}} \tag{7}$$

Using this formula, the compensator thickness of different region such as head, neck, Knee, calf, and ankle of Perspex material will be calculated and the compensators will be kept in the appropriate place to compensate the nonuniform thickness of the patient.

The thickness (T) required for the aluminium compensator for different region was calculated using the following formula:

$$\mu = \frac{0.693}{HVL}, \text{ Where HVL for aluminum material was measured to be 8 cm.}$$

$$T = \ln \frac{I}{I_0} \times 11.54 \text{ cm}$$

Aluminum compensator thickness (T)

$$= 11.54 \times \ln \frac{\text{Midplane dose of the region}}{\text{Midplane dose of the umbilicus}} \tag{8}$$

To calculate the mid-plane dose of different regions, the following formula was used

Mid-plane dose of given region

$$= \frac{\text{dose at the midplane of umbilicus} \times \text{PDD of the given Region}}{\text{PDD of the umbilicus}} \tag{9}$$

Lung dose calculation

The lung dose calculation was calculated from the following formula:

$$\text{PDD} = \frac{\text{dose at any depth} \times 100\%}{\text{Dose at Dmax}}$$

From the above equation,

$$\text{Lung Dose} = \frac{\text{DMax Dose measured at arm level} \times \text{PDD of the Lung}}{100} \tag{10}$$

PDD of the lung can be calculated using the following formula:

$$\text{Depth of the lung} = \left(\frac{\text{Lateral Chestwall separation}}{2} \right) - (\text{Single Lung separation}) + (\text{single lung separation} \times 0.31) + (\text{single-arm separation}) \tag{11}$$

Single lung separation was taken from the electronic portal

imaging device during the initial measurement of the patient. Single arm and chest wall separation was taken from the initial measurement, and the lung density was considered as 0.31 g/cm³ (Air transmission factor).^[16] Using the depth of the lung, the corresponding PDD was taken from the commissioning data. Figure 1 shows the single-arm, chest wall and lateral lung separation.

In vivo dosimetry

QA is a manner of confidence check ensured by comparing the calculated dose with the measured dose. To measure the dose delivered, *in-vivo* silicon diodes ISORADTM (*in vivo* diodes [IVD] sun nuclear corporation) were placed on the surface of the patients and phantom. The cylindrical-shaped ISORAD detectors are 10 mm in diameter and it contains silicon diode with sufficient electronic equilibrium for radiation measurement. The diodes were calibrated before each use.

End to end validation

As part of compensator-based Bi-lateral TBI validation, end-to-end measurement was carried out with in-house rice-flour phantom (RFP) and IVD. The RFP was made in the shape of human anatomy by filling rice flour in cotton material. Figure 2 shows the photograph of RFP. The phantom was placed in a supine position on the treatment couch with bent knees. The separation of various regions of the phantom such as head, neck, shoulder, chest, umbilicus, thighs, knees, calf, and ankle was measured in the same position using a caliper. These separations were used in calculating MUs as well as compensator thickness of Perspex and aluminum using equations (4), (7), and (8), respectively. IVD diodes were placed over head, neck, umbilicus, knee, and ankle, on the surface of the phantom. The prescription dose for TBI QA was 200 cGy in 1 fraction, and MU was calculated for each side such that 100 cGy will be delivered to the midplane of the phantom from each side. Initially, the left side of the RFP was irradiated after placing aluminum compensators, after which the couch was rotated, and the right side was treated. The dose measured at different regions was compared to the calculated dose. Similarly, RFP was irradiated with the same MU using

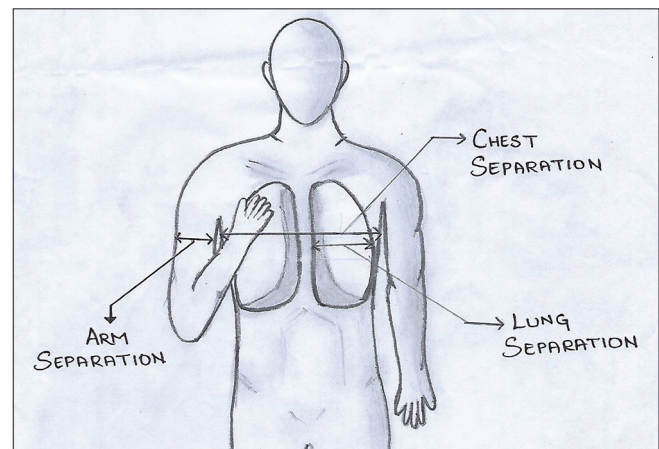


Figure 1: Shows the measurement of single-arm, chest wall, and lung separation for lung dose calculation

the Perspex compensator. Figure 3 shows the photograph of end-to-end verification with RFP and compensators.

After successfully validating TBI commissioning, two patients diagnosed with AML were treated with the bilateral TBI technique. The patients were positioned in the supine position with knees bent on the TBI couch. The patient separation was measured in different places using a caliper, and the dose and the aluminum compensator thickness were calculated. The dose prescribed for the first patient was 12 Gy in 8 fractions, and for the second patient, it was 2 Gy in 1 fraction. The compensator for lungs was used for the first patient to limit the lung dose within tolerance, and the lung compensator for the second patient was not used due to the less prescribed dose. The dose was measured using an IVD diode, and it was placed over head, neck, arm, umbilicus, knee, and ankle. The patients were treated like the QA procedure with patient-specific calculated MU and aluminum compensators. The IVD measured dose of both patients was compared to its respective calculated dose.

RESULTS

Percentage depth dose/skin dose analysis

The PDD was measured at 385 cm SSD for different beam spoiler distances from the phantom surface. Figure 4 shows the graph for PDD measurement with 10 cm, 20 cm, 30 cm, and 40 cm beam spoiler distance from the phantom surface. It was found that the surface dose measured varied with the distance of the beam spoiler from the phantom surface. Table 1 shows the PDD measurement for 40×40 cm² field size, collimator angle 45° with different beam spoiler distances. The Dmax was found to be 0.2 cm when the beam spoiler was kept at 10 cm and 20 cm distance from the phantom surface. For 30 cm and 40 cm distance, Dmax was found at a depth of 0.3 cm and 0.4 cm, respectively. Dose at Dmax with beam spoiler at different distances such as 10 cm, 20 cm, 30 cm, and 40 cm was 0.0729 cGy/MU, 0.0728 cGy/MU, 0.0723 cGy/MU, and 0.0723 cGy/MU, respectively, at 385 cm SSD. Figure 5 shows



Figure 2: Shows the photograph of rice flour phantom in supine position on the treatment couch with bent knees

the graph of surface dose analysis with PDD for different beam spoiler distances.

Profile measurement

The cross line profile dose relative to the CAX was measured in the range ± 120 cm from the CAX. The dose difference from the CAX was calculated in percentage, and the results showed that the dose difference was within $\pm 5\%$ compared to the CAX dose, in the range of ± 85 cm from the CAX. Therefore the results clearly show that patient length up to 170 cm can be treated within $\pm 5\%$ dose difference from CAX, with collimator 45° and field size 40×40 cm². From the cross line profile, flatness and symmetry results were 104.8% and 100.2%, respectively. Figure 6 shows the graph for the crossline profile measured with FC65 ion chamber at 10 cm depth for 385 cm SSD.

Half-value layer measurement

The HVL measured for perspex and aluminum material was 17 cm and 8 cm, respectively. Using these HVL values, the linear attenuation coefficient was calculated using formula (6), and the thickness required for different regions was calculated.

Mayneord factor corrected percentage depth dose

Using Mayneord factor formula, the corrected PDD was calculated at extended SSD.^[15] The corrected PDD values at extended SSD were compared with the measured PDD values. The results were showing that the difference was very minimal after 1 cm depth.

To validate the Mayneord factor corrected PDD, 100 cGy dose was prescribed to 12 cm depth and the MU's were calculated. Using Mayneord factor corrected PDD, MU was calculated and compared with the measured MU. The result was showing 7.6% percentage of deviation from the measured MU. Similarly, the comparison of calculated dose from reference distance (100 cm SSD) with measured dose at extended SSD was done. The result showed 7.0% percentage of deviation between the measured dose and calculated dose with Mayneord factor PDD.

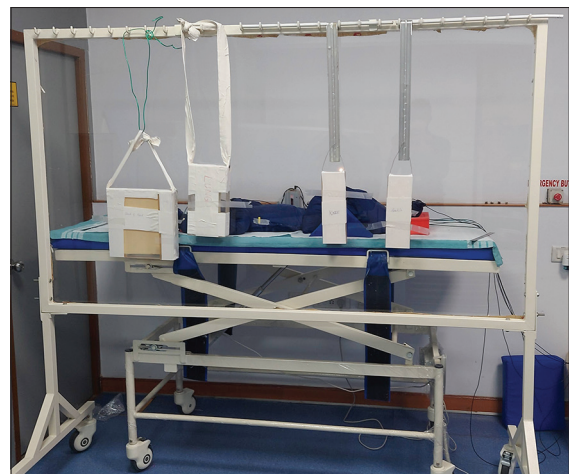


Figure 3: Shows the photograph of end-to-end verification with rice-flour phantom and compensators

Table 1: The percentage depth dose measurement for 40x40 field size, collimator angle 45° with different beam spoiler distances at 380 cm source to surface distance

Depth (cm)	PDD (cm)			
	10	20	30	40
0	98.00	97.30	97.10	96.50
0.1	99.38	99.04	99.18	98.62
0.2	100	100	99.46	99.17
0.3	99.45	99.59	100	99.31
0.4	99.45	99.59	99.88	100
0.5	99.45	99.59	99.76	99.86
0.6	99.42	99.51	99.64	99.72
0.7	99.31	99.42	99.52	99.64
0.8	99.27	99.34	99.4	99.45
0.9	99.19	99.26	99.28	99.31
1	99.11	99.18	99.17	99.17
2	97.97	97.94	97.94	98.06
3	95.83	95.74	96.20	95.99
4	93.13	93.13	93.60	93.50
5	90.69	90.66	91.15	91.09
6	88.04	88.21	88.67	88.56
7	85.53	85.62	86.09	86.03
8	83.02	83.02	83.50	83.54
9	80.50	80.52	80.91	80.91
10	77.98	78.02	78.33	78.28
11	75.47	75.49	75.77	75.80
12	72.95	72.97	73.21	73.17
13	70.54	70.58	70.98	70.82
14	68.14	68.19	68.75	68.52
15	65.73	65.8	66.52	66.11
16	63.51	63.58	64.29	63.97
17	61.29	61.36	62.06	61.80
18	59.07	59.13	59.83	59.61
19	56.98	57.01	57.60	57.40
20	54.90	54.89	55.37	55.19
21	52.81	52.77	53.14	53.11
22	50.96	50.9	51.23	51.19
23	49.10	49.03	49.32	49.24
24	47.24	47.16	47.41	47.30

PDD: Percentage depth dose

End to end measurement

Using separations of in-house RFP, the PDD for each region was determined from the PDD table. As the dose is prescribed to the umbilicus, treatment MU was calculated using PDD of the umbilicus region. Then the compensator thickness required to reduce the mid-plane dose of other regions was calculated. Table 2 shows the Perspex and aluminum compensator thickness and the surface dose measured by IVD diodes. It also shows the percentage of deviation of calculated dose from measured dose with Perspex and aluminum compensator. The dose deviation for head, neck, umbilicus, knee, and ankle was 4.46%, 0.88%, 4.63%, 1.26%, and -1.33%, respectively, for Perspex compensator. For aluminum compensator, dose

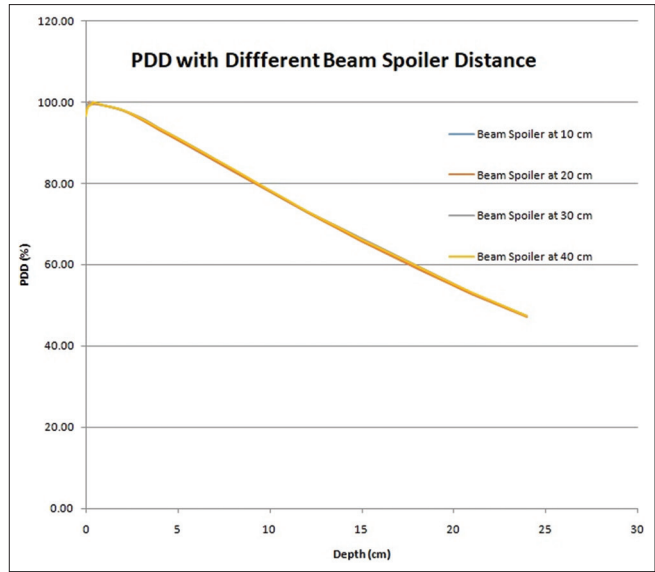


Figure 4: Shows the graph for percentage depth dose measurement with 10 cm, 20 cm, 30 cm, and 40 cm beam spoiler distance from the phantom surface

deviation for head, neck, umbilicus, knee, and ankle was 3.52%, 0.48%, 4.71%, 0.76%, and -1.07%, respectively. The cumulative percentage of deviation was less than ± 4.8% between IVD measured and calculated dose for both Perspex and aluminum compensator for the RFP.

Tables 3 and 4 show the PDD for different regions, compensator thickness, and measured dose for Patient one and Patient two. For Patient one, lung dose was measured during the first fraction of TBI, and it was found to be 106.26 cGy after placing the lung compensators (Perspex). Following the approval of oncologists, the lung compensator of the same thickness was used throughout all eight fractions of treatment, and the lung dose was measured to be 850 cGy cumulatively. The cumulative percentage of deviation for patient one and patient two are less than ± 3.29% and ± 3.4%, respectively.

DISCUSSION

TBI has been used as a conditioning regimen for AML and ALL stem cell transplant protocol for several years. The most commonly used technique in TBI treatment is parallel opposed beam and AP/PA (Anterior to Posterior/Posterior to anterior) at extended SSD. In the AP/PA treatment technique, lung shielding can be done by placing a cerrobend block on the beam path.

Our institution commissioned compensator-based bilateral extended SSD TBI with a beam spoiler thickness of 1 cm for Elekta™ Synergy treatment machine. The commissioning of this TBI was implemented as per the AAPM report no. 17.^[17] In the bilateral TBI technique, the thickness of the patient’s body will not be uniform from the lateral view. To compensate for the nonuniform thickness of the patient, aluminum and perspex compensators were used in the commissioning procedure. The

Table 2: The percentage of deviation, perspex and aluminum compensator thickness and the surface dose measured by *in-vivo* diodes with rice-flour phantom

Position	Separation (cm)	PDD (%)	Mid plane dose without compensator	Compensator thickness (cm)	Diode reading with compensator (Dmax dose)	Mid plane dose with compensator $D=(D_{max} \times PDD)/100$	Percentage of deviation (%)
Perspex compensator							
Prescribed dose at mid plane region (100 cGy from each side)							
Skull	14.7	84.58	115.91	3.6	123.5	104.46	4.46
Neck	7.5	93.65	128.34	6.1	107.7	100.86	0.88
Umbilicus	24.0	72.97	100.00	0.0	143.4	104.63	4.63
Knee	15.0	84.32	115.55	3.5	120.1	101.26	1.26
Ankle	14.1	85.36	116.98	3.8	115.6	98.67	-1.33
Aluminium compensator							
Prescribed dose at mid plane region (100 cGy from each side)							
Skull	14.7	84.58	115.91	1.7	122.4	103.52	3.52
Neck	7.5	93.65	128.34	2.9	107.3	100.48	0.48
Umbilicus	24.0	72.97	100.00	0.0	143.5	104.71	4.71
Knee	15.0	84.32	115.55	1.7	119.5	100.76	0.76
Ankle	14.1	85.36	116.98	1.8	115.9	98.93	-1.07

PDD: Percentage depth dose

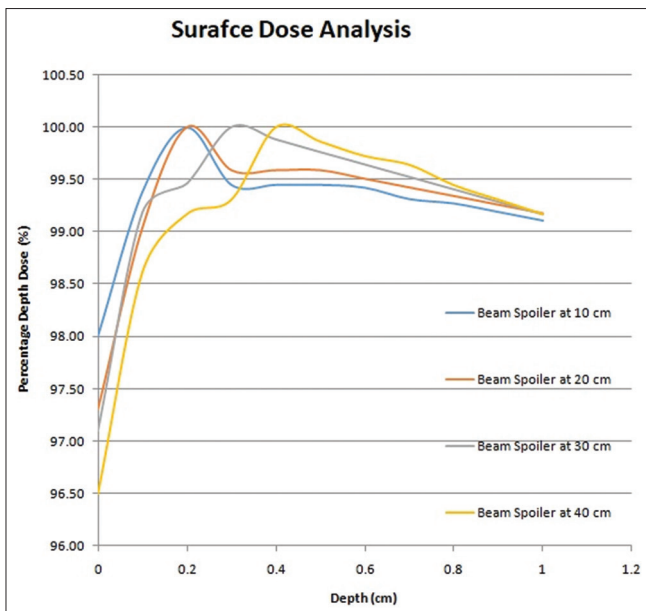


Figure 5: Shows the graph of surface dose analysis with percentage depth dose for different beam spoiler distances

surface dose analysis was done for each PDD measured at a different beam spoiler distance. The Dmax was found to be 0.2 cm when the beam spoiler was kept at 10 cm and 20 cm distance from the phantom surface. For 30 cm and 40 cm distance, Dmax was found at a depth of 0.3 cm and 0.4 cm, respectively. The surface dose analysis showed that whenever the beam spoiler distance increased from the phantom surface, the Dmax also increased. After 1 cm depth, there was not much difference between PDD results for different beam spoiler distances.

The cross line profile dose relative to the CAX was measured in the range ± 95 cm from the CAX. The profile result

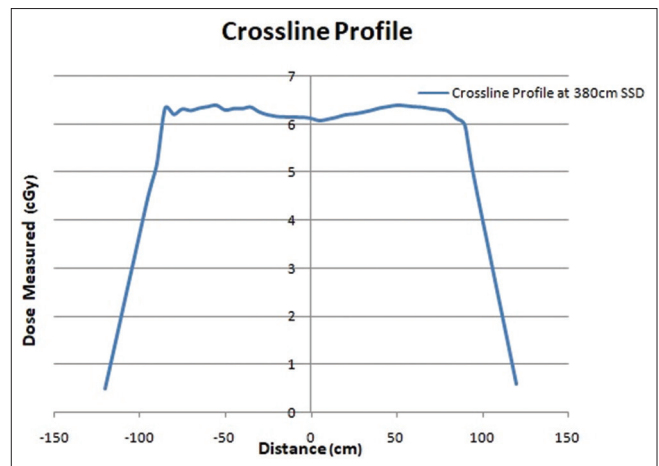


Figure 6: Shows the graph for the Crossline profile measured with FC65 ion chamber at 10 cm depth for 385 cm source to surface distance

clearly shows that patient length up to 170 cm can be treated within $\pm 5\%$ dose difference with this bilateral treatment technique. The flatness and symmetry of the cross line profile were 104.8% and 100.2%, respectively. The Mayneord factor corrected PDD values at extended SSD were compared with the measured PDD values. The results were showing that the difference was very minimal after 1 cm depth.

The validation of TBI commissioning was done using RFP with IVD diodes. The dose received at different regions was measured and compared with the calculated dose of RFP. After the commissioning and validation of TBI, two patients were treated with the same TBI technique and procedure. The cumulative difference of IVD measured dose with the calculated dose for patient one and patient two are less than $\pm 3.29\%$ and $\pm 3.4\%$, respectively. To bring the lung dose

Table 3: The percentage depth dose for different regions, compensator thickness, and measured dose for patient 1

Prescribed dose at mid plane region (75 cGy from each side)							
Position	Separation (cm)	PDD (%)	Mid plane dose without compensator	Aluminum compensator thickness (cm)	Diode reading with compensator (Dmax dose)	Mid plane dose with compensator D=(Dmax×PDD)/100	Percentage of deviation (%)
Skull	14.7	84.58	88.39	1.9	90.4	76.46	1.94
Neck	9.0	91.9	96.04	2.9	80.6	74.07	-0.99
Umbilicus	25.0	71.77	75.00	0.0	105.6	75.78	+1.05
Knee	18.9	79.27	82.84	1.1	91.5	72.53	1.26
Calf	18.0	80.52	84.14	1.3	95.9	77.21	+2.94
Ankle	12.7	87.18	91.10	2.2	85.1	74.19	-0.28

PDD: Percentage depth dose

Table 4: The percentage depth dose for different regions, compensator thickness, and measured dose for patient 2

Prescribed dose at mid plane region (100 cGy from each side)							
Position	Separation (cm)	PDD (%)	Mid plane dose without compensator	Aluminum compensator thickness (cm)	Diode reading with compensator (Dmax dose)	Mid plane dose with compensator D=(Dmax × PDD)/100	Percentage of deviation (%)
Skull	14.4	85.1	129.33	3.0	116.1	98.8	-1.20
Neck	8.7	92.14	140.03	3.9	108.5	99.97	-0.03
Umbilicus	29.9	65.8	100	0.0	157.1	103.37	+3.37
Knee	19.2	79.02	120.09	2.1	123.6	97.89	-2.11
Calf	18.5	79.77	121.23	2.2	122.4	97.90	-2.10
Ankle	14.9	84.32	128.15	2.9	118.2	99.66	-0.34

PDD: Percentage depth dose

within tolerance limit, a lung compensator was used for the first patient. To determine the lung dose in 2 Dimensional (2D) TBI treatment technique no precise formula has been found in literature. This study also focuses on lung dose calculation using 2D TBI treatment.

Commissioning of different TBI techniques was done in various institutions. Aldrovandi *et al.* have commissioned the 3D arc-based TBI technique. This arc-based TBI technique was implemented using Eclipse TPS (analytical anisotropic algorithms (AAA) dose calculation algorithm) in a small treatment room (extended SSD 200 cm) and short treatment time.^[12] The use of TPS to calculate MU for TBI is not recommended in the literature, although it can be used for a rough estimate of patient dose. In the same literature, plastic bags were used to compensate for the nonuniform thickness of the patient’s body in bilateral TBI technique instead of perspex or aluminum compensators.^[13] The *in-vivo* dosimetry plays an important role in the treatment of TBI. The *in-vivo* dosimetry can be performed with diodes, TLD chips, EBT2 films, or MOSFET detectors to ensure accurate treatment delivery. To check the dose homogeneity, the dose received at different places can be measured using TLD, semiconductors, and ionization chambers.^[18,19]

Lung dose calculation in TBI is a crucial part of the treatment. Many TPS are available to calculate the lung dose at extended SSD, but the accuracy of dose calculation at 400 cm SSD is to be questioned. The accurate lung dose calculation using

a compensator or cerrobend block is an integral part of TBI treatment. The TPS calculated lung dose with AAA and AXB algorithms had more deviation with measured dose while using the cerrobend block as a shielding material.^[20] Our study calculated the lung dose using the surface dose measured at the arm level with IVD diodes. The lung dose was calculated using lung separation and depth dose measured before TBI treatment from the measured dose.

CONCLUSION

Commissioning of different TBI techniques was done in various institutions. After reviewing several research papers, the bilateral extended SSD TBI technique was commissioned and established in our institution for Elekta™ Synergy treatment machine, 6MV photon beam with a beam spoiler thickness of 1 cm. Institutions where 2D TBI treatment techniques are to be implemented, can use this methodology of calculation of lung dose and mid-plane dose for various regions.

The commissioning of the compensator-based TBI technique was performed and its QA measurements were carried out. The Mayneord factor corrected PDD and measured PDD value results were compared and it shows that the difference was very minimal after 1 cm depth. Surface dose analysis was performed with different beam spoiler distances from the phantom surface. The depth of Dmax increases when the beam spoiler is moved away from the phantom surface. This study concludes that to create a uniform dose to the entire body during TBI, the beam

spoiler can be placed at a distance ranging from 10 cm to 20 cm to achieve the required skin dose.

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Conflicts of interest

There are no conflicts of interest.

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