Total body irradiation (TBI): Preliminary experience on clinical implementation

Sir,

A recent publication[1] enumerated a dose analysis in the treatments with total body irradiation (TBI) through *in-vivo* dosimetry. In our hospital we started TBI last year, based on a protocol developed using the beam configuration and methods reported earlier.[2,3] TBI is used as a conditioning regimen prior to bone marrow transplantation (BMT) for the management of various types of leukemia, malignant lymphoma, and aplastic anemia. TBI is also used in the treatment of systemic malignant spread and bone pain due to metastases. Before engraftment of donor bone marrow, pre-transplant conditioning is applied to eradicate the tumor cells or cells with genetic disorders.[4] Most common form of pre-transplant conditioning is a combination of high dose chemotherapy and TBI. TBI helps to prevent the failure of the graft by resulting in immune-suppression. Most of the radiotherapy clinics use 6 MV x-rays for these treatments with a prescribed total dose of 12 Gy in six fractions, at two fractions per day (separated by a minimum of 6 h) over 3 days.[4] A homogeneous dose within ±10% and treatment delivery to include skin to 100% dose are some of the other criteria. Dose delivered per min (dose rate) is a factor that influences biological effects of TBI, and the accepted practice is to keep the dose rate between 0.05 and 0.10 Gy/min (<10 cGy/min).[5]

Dosimetric aspects of magna field irradiations and use of entrance and exit detectors for clinical dosimetry are well discussed in literature.[6-9] The effect of TBI dose fractionation on pulmonary complications was found insignificant with 12 Gy whole body dose delivered in six fractions in 3 days or in four fractions in 2 days.[10] A review of reports published on TBI from established centers[11] has shown biological effective dose to kidneys (BED_{kidney}) ranging from 14.0 to 28.0 Gy. Using regression analysis they indicated that there may be need for shielding kidneys at an equivalent dose of 16 Gy BED_{kidney}.

TBI is carried out in our clinic using Clinac 600 CD linear accelerator at 4.0 m focus skin distance, along with a locally fabricated acrylic beam spoiler of dimensions 2.0 M × 0.7 M × 0.015 M. As reported earlier, a near perfect flat beam of specifications 100 ± 0.4% is achieved using an added flatness filter[2] at the exit portal of the linac. A pulse repetition rate of 100 MU/min setting, corresponded to a dose rate of 6.7 cGy/min at 4.0 m focus skin distance. At this treatment distance a diamond shaped magna field is achieved which has diverged enough to cover a patient total height of more than 2 m. The objective of the beam spoiler is to degrade the original quality of the 6 MV photon beam which has dose build up occurring at 15 mm. With the present treatment configuration, an entrance dose pattern 100, 99.4, 98.7, 96.8, and 94.7%, respectively at skin, 3, 5, 10, and 15 mm depths is achieved. For dose delivery calculations, 1.5 cm depth normalized percentage depth doses for the magna field are 100, 91.6, 78.6, 66.3, 55.1, and 45.7% at 1.5, 5, 10,15, 20, 25 cm depths, respectively. Attenuation factors for beam spoiler F_{BS} (0.970) and beam flattening filter F_{FF} (0.962) are to be applied on the measured dose/MU (6.84 cGy/100 MU) for treatment planning.

Treatment planning is carried out with computed tomography (CT) scan of the whole body, with 5 mm slices, with patients in supine position. The dose prescription is at the plane of umbilicus. Using radiological thickness estimates at skull, neck, shoulder, chest, umbilicus, knee and ankle levels, midplane doses at other levels are compensated to achieve dose uniformity, using 30 × 30 size acrylic plates. We standardized earlier a method for lung shielding for lateral recumbent positioning of the patients.[3] However, we found that for patient lying supine is more comfortable, and it can also facilitate for eye shielding, if necessary. Further, position of arm along the side can compensate for excess transmission of lung, due to its lower density. (Taking one-third tissue density equivalence for lung, our manual calculations showed that the extra thickness of hands at the lateral side compensated well for the effective radiological thickness of lung included in the path of the beam).

Three patients referred from Sultan Qaboos University Hospital received TBI treatments since 2012. A dedicated treatment table operated by direct current (DC) motor is used for patient set up. The monitor units required for 100 cGy at midplane were 2,412; 2,256; and 1,824 MU; respectively for each field in these three patients. One of the three patients had eye shielding during all six fractions. Direct patient dosimetry (DPD) was carried out using semiconductor detectors (Multi-dos, Scanditronix) in the first two fractions, to confirm efficacy of used acrylic plate compensator thickness and making fine adjustments. For clinical dosimetry, *in vivo* thermoluminescent detectors (TLD) were kept in the entry-exit locations at four planes representing skull, chest, umbilicus, and knee levels to estimate the delivered dose in TBI in all the six fractions, using method described in an earlier work.[12]

Our DPD dose estimates (represented by 2nd fraction measurement) for the three patients showed good uniformity in doses delivered to the whole body. The midline dose estimates achieved for the three patients were 2.036 (±4.4%), 1.964 (±0.8%), and 2.006 (±0.02%) Gy, respectively for a planned dose of 2 Gy. The whole body TLD dose estimates (mean of all six fractions) were 2.05 (±7.0%), 2.00 (±3.4%), and 2.05 (±1.8%) Gy for three patients. It could be observed that our data on TBI dose delivery showed good uniformity as per clinical requirements. A published 'Medline search'[11] found the biological effective dose to kidneys (BED_{kidney}) in the range of 14.0-28.0 Gy for various TBI regimens. By a regression analysis fit, a recommendation was made indicating the need for kidney shielding at an equivalent dose of 16 Gy BED_{kidney}. Our planned dose of 12 Gy in six fractions/3 days has an equivalent BED_{kidney} 20.2 Gy in comparison to the recently published cohort of patients (12 Gy in eight fractions/4 days with BED dose of 19.25 Gy).[1] This is due to same dose of 12 Gy delivered in larger number of fractions in 4 days. From the experience in positioning first two taller patients for treatment, we felt the need for increasing the diagonal field size of $180\sqrt{2} = 254$ cm by using source to skin distance (SSD) 4.5 M. The MU/min may also be changed to 200 MU/min which will give 9.87 cGy/min at 4.5 M, which is still within the accepted dose rate for TBI (<10 cGy/min).[5] This brief communication highlights the salient features of TBI technique implemented at our hospital which conformed to our clinical specifications.

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Ramamoorthy Ravichandran[1], Johnson Pichy Binukumar[1], Cheriyathmanjiyial Antony Davis[1], Zakia Al Rahbi[1], Rajan Balakrishnan[2], Zahid Al Mandhari[2]

[1]Medical Physics Unit, [2]Department of Radiation Oncology, Royal Hospital, Muscat, Sultanate of Oman

Address for correspondence:
Dr. Ramamoorthy Ravichandran,
Medical Physics Unit, National Oncology Centre, Royal Hospital,
PBox 1331, PC 111, Muscat, Sultanate of Oman.
E-mail: ravichandranrama@rediffmail.com

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