BEAM FILTER AND COMPENSATORS DURING TOTAL BODY IRRADIATION ON COBALT-60

Julian Malicki

Greatpoland Cancer Center, Garbary 15, 61-866 Poznań, Poland
Received 14 October 1997; revision received 21 January 1998; accepted 9 February 1998.

Summary

Total body irradiation performed with a combination of lateral and anterior – posterior fields was used prior to bone marrow transplantation. Dose discrepancies in a body during lateral fields were caused by different distances from the source to the particular body parts, different thickneses of body sections in ten reference levels and differences in interior tissues density. To improve dose homogeneity a radiation filter and individual compensators were used in the beam.

Dose deviations at the points representing patient's side and midline were counted and measured in a water tank and then for a patient taken as an example. Deviations were measured for the open field, filtered field and for the field with the filter and compensators.

For a patient taken as an example standard dose deviations for all ten sections were 17.0% in midline and 7.1% in side for an open beam and 9.8%, 4.8% respectively for the beam with the filter and compensators. Mean percent deviations from the dose in the central axis were –3.1% (midline) and –2.5% (side) for open, and –0.1% and 0.9% for the filtered and compensated beams, respectively.

Introduction

Total body irradiation (TBI) with the use of large lateral fields or combination of lateral and anterior-posterior fields and/or other fields remains an effective procedure in patient's preparation process prior to bone marrow transplantation in some disseminated malignancies [Cosset et. al., 1989; Inoue et. al., 1993; Belkacemi et. al., 1995; Wachowiak et. al., 1995; Wu et. al., 1994; Kolb et. al., 1988] Often the whole process is divided into fractions and spread in time between two and four days with the aim of decreasing the occurence of acute reactions in the lungs [Peters et al, 1979]. The decision of about the use of a particular source of radiation, i.e. Cobalt–60 or linear accelerator, often depends on its availability. However, this decision implies dose distributions and the choice of an irradiation technique [Sanchez – Doblado et al, 1995].

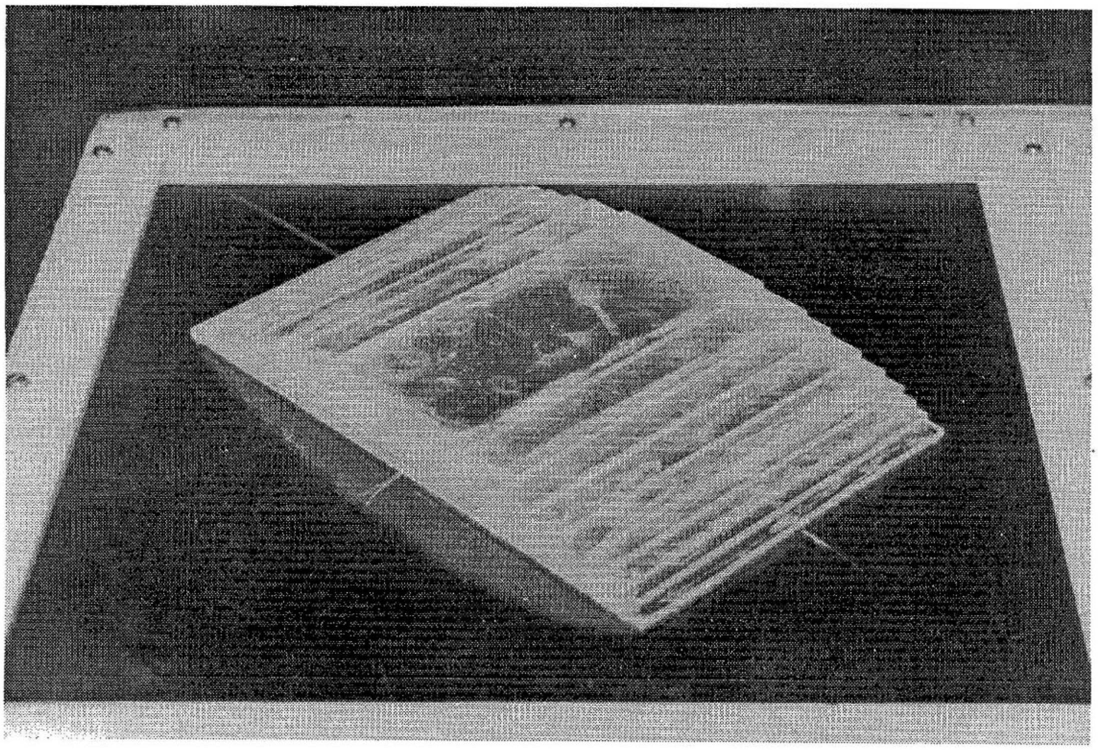
The main problem of TBI is to obtain homogenous doses inside a body and an appropriate dose reduction in the lungs [AAPM 29, 1986; Sanchez-Doblado et. al., 1995; Rittmann 1990; Laber et al., 1992]

The main aim of this paper and the applied method of irradiation was to improve the dose homogeneity inside a body by introducing into the beam a radiation filter and compensators.

Methods

Total Body Irradiation was performed with the use of a combination of large lateral fields and anterior - posterior (AP/PA) fields. A total dose of 12.6 Gy (in midline and central beam axis) was delivered in 8 fractions (4 days). A dose of 8.2 Gy was delivered from lateral fields with a dose rate of 6.67 cGy/min and a dose of 4.4 Gy from anterior - posterior fields with a dose rate of 17.70 cGy/min, respectively. Gammatron S with Cobalt-60 was used as a source of radiation. During lateral fields patient was positioned at a source to the body surface distance (SSD) of 275 cm and in AP/PA fields at 183 cm, respectively [Malicki et al., 1995]. An irregular body shape, its composition and beam geometry caused differences in distances from the source to various body parts during irradiation from lateral fields. Significant differences appeared especially in the distances from the source to head and to abdomen or feet. During AP/PA fields, a split of 2-3 fields was used to irradiate the whole body, part after the part, so that the differences in distances between the source, head and abdomen were much less significant. A larger distance from the source caused a lower intensity of radiation and consequently a lower dose absorbed. The thicknesses of the various sections of the body were also different, ie. head was 17 cm, abdomen was 27 cm and feet was 14 cm. This led to a dose decrease in thicker sections. Changes in the inner body density was accounted for only in the lung section. They caused smaller attenuation of the radiation and, consequently, higher dose absorption in the lungs. Dose unhomogeneity in the whole irradiated body was described by dose deviations along the body midline and between body sides and the midline.

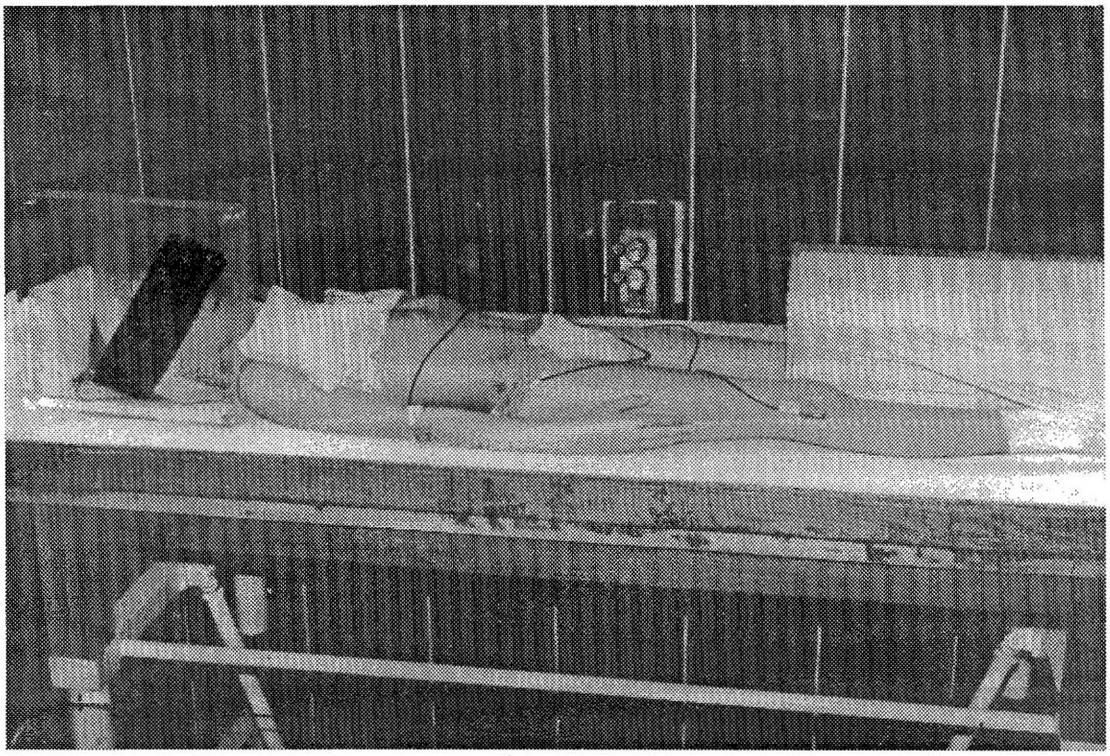
To minimize the dose deviations and to improve dose homogeneity a set of radiation filters and individual compensators were introduced during lateral fields. The aim of the filter was to atenuate excessive radiation. The filter was made from plexi of variable thickness calculated on the basis of the properties of the attenuating material used. To obtain a filter shape doses were measured accros the beam in a water tank at a depth of 0.5 cm in a range from -80 cm to +80 cm, perpendicularly to the central axis. The tank was placed at a distance of 275 cm from the source along the diagonal of the open square field. The filter shape is shown in photograph 1.



Photograph 1. Radiation filter for lateral fields in Gammatron S (Co-60).

Differences in thicknesses of particular body parts were compensated for with a soft tissue equivalent material (boluses) attached to the body. Body thicknesses and density were determined from tomography scans taken from the sections of the head, neck, shoulders, lungs, abdomen, wrists, central axis, knees and feet. These sections were chosen because of (1) the presence of important inner organs, (2) the complication of the body contour and (3) the possibility of reproducible and stable attachement of detectors on the body surface.

Individual compensators were attached at the head, neck, knees and feet. Thicknesses of compensators followed: at head 3.5 cm, at neck 5.5 cm, at knees and feet 6.5 cm. The positions of the compensators were shown in photograph 2.



Photograph 2. Position of compensators during lateral fields.

Results

In figure 1 normalised dose distributions, calculated and measured in a water tank at a depth of 0.5 cm perpendicularly to central axis, are shown for open and filtered beams. The doses were measured across the diagonal (x), and normalised to a dose value at the central axis.

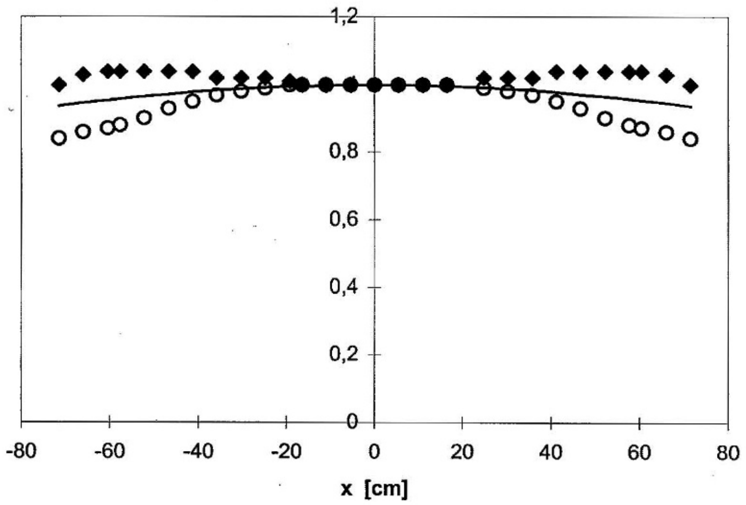


Fig. 1. Normalised dose distributions across the diagonal (x) in a water tank perpendicularly to the central beam axis. Calculated doses for an open beam are shown by a solid line. Measured doses: without filter (o) and with filter (♦) are represented by a dotted line.

Table 1 lists the percent dose deviations (DEV) from dose in central axis, measured in a water tank for open and filtered beams. Doses were measured along the field diagonal at the places corresponding to chosen body parts. Measurements were carried at a depth of 0.5 cm, which represented the side of patient's body. In the two bottom rows mean and standard deviations for all ten sections are shown as percentage of the dose at the central axis.

	DEV [%]	
	open	filtered
Head	- 3.6	0.3
Shoulders	- 1.7	0.3
Lungs	- 1.0	0.3
CAX	0	0
Feet	- 3.8	-0.1
Mean	- 1.4	0.3
STD	1.3	0.5

Table 1. Dose percent deviations (DEV) from the dose in the central axis measured in a water tank for open and filtered beams. In two bottom rows mean and standard (STD) deviations for all ten sections are shown.

Table 2 shows dose percent deviations (DEV) from the dose in the central axis for a patient taken as an example for the midline, and for the body side in chosen sections. Doses were calculated for an open beam, a filtered beam and for the beam with the filter and compensators. For the beam with filter and compensators, the measured doses for a body side are shown additionally in italics. In two bottom rows mean and standard deviations (STD) are shown, respectively.

	DEV [%]						
	open		filter		filter+compensator		
	side	midline	side	midline	side		midline
Head	- 0.9	1.1	3.1	5.1	0.4	*0.5*	- 2.5
Shoulders	-11.8	-22.1	-10.1	-20.5	-10.1	*- 9.5*	-20.5
Lungs	- 9.5	32.5	- 11.6	35.1	- 3.8	*- 3.4*	12.7
CAX	0	0	0	0	0	*0*	0
Feet	8.8	13.9	13.2	18.5	8.7	*8.9*	8.6
Mean	- 2.5	- 3.1	0.2	- 0.3	0.9	*0.7*	- 0.1
STD	7.1	17.0	6.9	16.5	4.8	*- 5.0*	9.8

Table 2. Dose percent deviations (DEV) from the dose in the central axis for the patient taken as an example calculated for the body side and midline for an open field, filtered beam and for the beam with filter and compensators. The measured dose deviations are shown in italics. Two bottom rows represent: mean and standard deviations (STD) for all ten sections.

Discussion

During irradiation, both the water tank and the patient were positioned along a square field diagonal to obtain a larger homogenously irradiated area.

The slopes of the dose distributions measured for an open beam are seen to fall near field edges. This fall was larger than that calculated which resulted from the increase in the distance (fig. 1). This could have been caused by the coliminating jaws in the Gammatron-S Cobalt unit, which absorbed and scattered radiation on field edges. Dimensions of the source (approx 2.5 cm length) were also responsible for the increased distortions in the field profile. The influence of radiation scattered in the water tank was partialy taken into account. Tank dimensions were 40 cm x50 cm x40 cm, and the tank was moved during measurements to simulate the length of the positioned patient. The position of the detector inside the tank was also moved from the tank wall to its center to simulate the attachements of the detectors at the head and abdomen.

The application of the filter equilibrized dose distributions along the field diagonal (fig. 1) and resulted in lower mean deviations from CAX and lower standard deviations both measured in the water tank and in body side (table 1 and table 2). The advantage was visible in the simulated head section lying near the field edge, where the dose should be determined exactly (table 1).

The use of a water tank (equivalent to soft tissue) for dose measurements also allowed avoiding the influence of the backscatter generated in the walls, because the low back scattered energy radiation was mostly absorbed in water.

During patient's irradiation the doses were measured in the beam to the body entry and exit. The doses in both body sides were equal because the patient was rotated after half of the fractional dose was delivered.

The density was only taken into account in dose calculation and in the additional compensation in the lung section. The use of a 3.5 cm compensator decreased the dose in the lungs from +35.1% to +12.7% (table 2). Still the excesive dose in the lungs after lateral fields was not hazardous because the lungs shielding was used later during anterior – posterior fields. 6.5 cm thick compensators in legs (knees, feet) were needed because of the much smaller thickness of the legs. They decreased the dose deviations in feet from 18.5% to 8.6%.

Tables 1 and 2 show doses only in five, out of ten sections under consideration because in these sections the doses were excesive and the compensators had to be used. However, the mean and standard deviation were counted for all ten sections. Standard dose deviations calculated for all ten sections showed homogeneity of the dose delivered, while the mean deviations from the prescribed doses indicated mean underdosage or overdosage in the whole body.

Conclusions

A beam filter and compensators during lateral fields decreased the standard dose deviations in a body from 17.0% in the midline and 7.1% in side to 9.8% and 4.8% respectively.

The beam filter and compensators allowed us to increase the mean dose to the body and to decrease dose deviations from the prescribed dose in the central axis: from –3.1% (midline) and –2.5% (side) for the open field to –0.1% and 0.9% for the fillered and compensated field, respectively.

References

AAPM Task Group 29. The physical aspects of total and half body photon irradiation. American Institute of Physics, New York, 1986 Report 17 .

Belkacemi Y, Rio B, Laporte J P, Leblond V, Pene F, Langier A. Is veno - Occlusive Disease Incidence influenced by the Total Body Irradiation Technique? Strahlenther. Onkol. 171 (1995) 694-697.

Cosset J M, Baume D, Pico J L ,Shank B, Girinski T, Bwnhamou E, Briot E, Malaise E, Hayat M, Dutreix Single dose versus hyperfractionated total body irradiation before allogeneic bone marrow transplantation: a non-randomized comparative study of 54 patients at the Institut Gustave-Roussy, Radiother. Oncol. 15 (1989) 151-160.

Inoue, T, Ikeda H, Yamazaki H. Role of total body irradiation as based on comparison of preparation regimens for allogege bone marrow transplantation for acute leukemia in first complete remission. Strahlenther. Onkol. 169 (1993) 250-255.

Kolb H J, Gratiwohl A, Zwaan F E. Randomized study comparing busulfan and cyclophosphamide with total body irradiation with cyclophosphamide as conditioning treatment for allogenic bone marrow transplantation patients with leukemia. Protocol of Acute Leucemia working Party. European Cooperative Group for Bone Marrow Transplantation (EBMT) 1988.

Malicki J, Kierzkowski J, Kosicka G, Górny A, Stryczyńska G, Wachowiak J. Calculation and in vivo dose distribution verification in fractionated total body irradiation. Nowotwory. 45 (1995) 39-45 (in polish).

Malicki J, Kosicka G, Kierzkowski J, Górny A. Analysis of effectiveness and accuracy of ionization semiconductor and thermoluminescent detectors used in total body irradiation. Journal of Med. Phys. 21 (1996) 10-13.

Peters L J, Withers H R, Cundiff J H, Dicke K A. Radiobiological Considerations in the Use of Total Body Irradiation for Bone-Marrow Transplantation. Radiology 131 (1979) 243-247.

Rittmann K L, Meinass H, Renicke P: Dose to Lung. Proceedings of a DGMP Working Group Seminar, Essen 1990.

Sanchez-Doblado F, Quast V, Arrians R, Errazquin L, Sanchez-Nieto B, Terrón J A. Total body irradiation prior to bone marrow transplantation. (EBMT) 1995.

Wachowiak J, Bettoni C, Lange A, Malicki J, Kaczmarek-Kanold M, Głuszak B, Suchnicki K, Daszkiewicz P, Ebell W. Can Busulfan replace fractionated total body irradiation as conditioning regimen for allogeneic bone marrow transplantation in children with acute lymphoblastic leukemia. Ac. Haem-at. Pol. 26 (1995) 377-383.

Wu D P, Milpied N, Moreau P, Mechinaud-Lacroix F, Mahe B, Le Tortorec S, Rapp M J, Bourdin S, Mahe J M, Harousseau J L. Total body irradiation and high-dose cyclophosphamide, BCNU and VP-16 (CBV) as a new preparatory regimen for allogeneic bone marrow transplantation in patients with advanced hematologic malignancies. Bone Marrow Transplant. 14 (1994) 751-757.