Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: http://www.elsevier.com/locate/rpor

Original research article

Dose distribution homogeneity in two TBI techniques—Analysis of 208 irradiated patients conducted in Stanislaw Leszczynski Memorial Hospital, Katowice

Aneta Kawa-Iwanicka, Włodzimierz Łobodziec, Marcin Dybek, Dorota Nenko, Tomasz Iwanicki*

Radiotherapy Department, Stanislaw Leszczynski Memorial Hospital, Katowice, Poland

ARTICLE INFO

Article history:
Received 8 November 2011
Received in revised form 5 June 2012
Accepted 17 July 2012

Keywords:
TBI
MOSFET dosimetry
Dose homogeneity
VMAT

ABSTRACT

Background: To analyze and compare dose distribution homogeneity in selected points (especially in the chest wall region) for patients irradiated with two different TBI techniques to achieve a uniform total dose (excluding lungs area) specified in the range of 11.4–14.0 Gy.
Material and methods: From August 2000 to December 2009, a group of 158 patients was treated by the use of 15 MV photon irradiation consisting of six fractions: four opposed lateral and two anterior–posterior/posterior–anterior (AP/PA). Patients were irradiated with the fraction dose of 2 Gy twice a day for 3 consecutive days. The prescribed dose to PC point (specified at intersection of the beam axis with the mid-plane of the patient irradiated laterally) was 12 Gy. Since January 2010 until closing the study, another group of 50 patients was treated according to a modified protocol. The treatment was carried out in six lateral fractions only, twice a day, for three following days and a lateral lung shield was used for a part of total irradiation time. The measurements of doses in 20 selected points of patient's body were carried out by means of MOSFET detectors.
Results: The modified TBI technique allows to achieve an expected homogenous dose in the points of interest similar to that obtained by using the initial protocol. The calculated and measured in vivo doses met the specified range of 11.4–14 Gy for both applied TBI protocols.
Conclusions: Our results indicate that for all patients the homogenous dose distribution in the specified range was achieved.

1. Background

For many years the total body irradiation (TBI) technique was a part of conditioning prior to Bone Marrow Transplantation (BMT) in hematological malignancies. This kind of therapy has been recognized as one of the most important treatments for hematological malignancies. It is used in conjunction with chemotherapy as a conditioning regimen for BMT or peripheral blood stem cell transplantation.[1–3] The main purpose of the irradiation is to suppress the patient's immune system and prevent bone marrow rejection from unrelated donors. TBI is

* *Corresponding author*. Tel.: +48 32 2050845; fax: +48 32 2050846.
E-mail address: anetaiwanicka@op.pl (A. Kawa-Iwanicka).

1507-1367/$ – see front matter © 2012 Greater Poland Cancer Centre. Published by Elsevier Urban & Partner Sp. z o.o. All rights reserved.
http://dx.doi.org/10.1016/j.rpor.2012.07.013

also a tool to eradicate abnormal cells which survived other therapies, such as surgery, chemotherapy or local irradiation, and which are hidden in the patient's body with potential to grow again.

TBI is generally delivered twice a day for two to five consecutive days. A number of techniques have been developed in different centers, and the choice of a technique depends on conditions available in a particular center.[4–13] Methods of TBI are the following: parallel-opposed lateral field's technique, parallel-opposed anterior–posterior/posterior–anterior (AP/PA) technique or a composition of lateral and AP/PA fields, divided into 4–10 fractions. Such a schedule allows normal tissues to repair radiation damage. The TBI technique usually yields in a very irregular extended field, therefore it is essential to achieve a homogenous radiation dose over the whole body. Such a task requires a very careful setup to minimize possible errors (recommended AAMP error range for TBI is −10% to +5%).[14,15]

In such an extended area, doses delivered in some points can be higher than those prescribed to a PC point by up to even ± 15%.[14] We can confirm previously reported results of other centers[14–17] that it is not easy to maintain narrow percentage deviation from planned dose.

The main goal in TBI is to maintain, as well as possible, dose uniformity over a large area of patient's body and keep critical organs, usually lungs, and in some reasonable cases kidneys or eyes, at the lowest possible level of doses.[16,18–24] Radiation oncologists determine the criteria of irradiation doses for organs at risk.

In the recent years, significant technological progress can be observed in the field of radiotherapy. It results in high quality of patients treatment, in which the most important factors are the accuracy of beam delivery and improved patient's comfort during irradiation. The last issue is directly related to the period of time that the patient spends on a treatment table in a therapy room. Both quality improvement factors can be assured by such techniques like Intensity-Modulated Radiation Therapy (IMRT), Image Guided Radiation Therapy (IGRT), Volumetric Modulated Arc Therapy (VMAT), Tomotherapy, etc.[25] Some new technological approaches have also been investigated and applied for TBI and Total Marrow Irradiation (TMI) therapies.[18,26–29] Over the last ten years, the TBI technique administered in our department has also been modified.

2. Aim

The target of this report is to present two ways of administering total body irradiation, as well as to analyze results and compare dose distribution homogeneity in 20 selected anatomical points (especially in the chest wall region) for patients irradiated with two modes of the TBI technique. The goal was to achieve the most uniform total dose (excluding lungs area) in the range of 11.4–14.0 Gy (i.e. 95–116% of 12 Gy prescribed to reference point PC-specified at the intersection of the beam axis with the mid-plane of the patient irradiated laterally). The percentage range is a result of dosimetrical conditions of our therapeutic devices (like measured dose profiles and PDD) and it is considered by radiation oncologists to be acceptable and safe for patients.

3. Materials and methods

The results of dose measurements and analyses of dose distribution were carried out for a group of 208 irradiated patients.

4. POLKAM table

POLKAM TBI Treatment Table is applied for reproducibility of patient positioning and fixation during irradiation of patient. It is composed of two separate parts: Positioning Table and Therapeutic Frame for patient immobilising during irradiation. In general, Polkam TBI Treatment Table was designed in our Department of Radiotherapy, manufactured by ZDAJ-HITEC company in Otwock-Świerk and awarded the 2008 "Teraz Polska" ("Now Poland") distinguishing mark.

Therapeutic Frame consists of two plates made of plexiglas sized 206 cm × 40 cm and 1 cm in thickness, placed parallel to each other and fixed together with a possibility to change the distance between them. The built-up effect takes place in the plexiglas plates, so that we can obtain a full prescribed dose to the patient's skin.[30–32] Two rows of markers are placed on the plates in a distance of 10 cm from each other to fix the characteristic points on the patient's body. These points are mapped on the skin during patient's simulation, and are helpful to achieve the same patient's positioning during each irradiation course (Fig. 1).

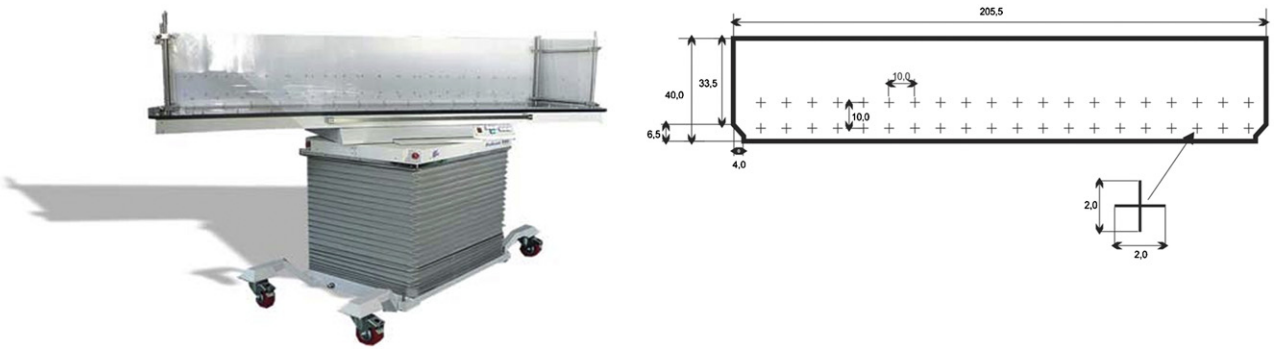


Fig. 1 – POLKAM TBI – total body table with special therapeutic frame.

Table 1 – Distribution of cases treated in the years 2000–2009.

Diagnosis	Number of cases
Leucemia limphoblastica acuta (ALL + CML)	109
Lymphoma malignum (NHL)	28
Lymphogranulomatosis malignum (LGM)	10
Plasmocytoma	11
Total	158

The therapeutic frame is equipped with an easily removable cover plate which protects knees during lateral irradiation (for maximum treatment field size, adult patients should be irradiated with bended knees). Therapeutic frame can also be used for patient positioning and immobilizing during AP/PA fractions. In this case, the therapeutic frame is placed on the accelerator's conventional treatment table.

4.1. *Initial mode of TBI application*

From August 2000 to December 2009, a group of 158 patients (age ranging from 2 to 63 years – see Table 1) were treated using the technique described in papers.[33,34]

The technique consisted of six fractions: four lateral opposed (SSD = 330 cm, field 40 cm × 40 cm at the distance of 100 cm, dose-rate 4.3 cGy/min) and two AP/PA (SSD = 135 cm field 40 cm × 40 cm at the distance of 100 cm, dose-rate 23.6 cGy/min). Each AP/PA fraction consisted of four pairs of opposing fields. Fields junction region (Fig. 2) was checked by separate measurements. Dose in the gap and overlap region did not differ substantially from the assumed homogeneity.[33] Photon beams of 15 MV were used.

The basic issue of dose distribution over the whole patient's body is the variation of their shape from head to feet. To improve the uniformity of dose distribution, the empty volume between the patient and the therapeutic frame walls was filled with bags of rice, constituting a bolus (Fig. 3). Patients were irradiated with fraction dose of 2 Gy, twice a day for three consecutive days. During the AP/PA and lateral fraction, Wood's alloy shields were used for lungs to maintain the total dose in lungs region below 9 Gy. Shield and patient positioning verification was checked before the first lateral fraction with a shield X-ray film and before AP/PA fraction with the use of an electronic portal film. The shape of each shield was traced on patient's skin for AP/PA fractions, and on the frame plexiglas wall for lateral fractions (see Fig. 3), after checking the shield location correctness. Markers on the patient's skin and these on the frame walls are helpful to achieve a proper location in subsequent fractions. These drawings can be used in the next shielded fraction, without having to do another portal or X-ray film. Electron boosts for the chest wall were delivered with lead electron apertures. The shape of these fields was an aperture of photon AP/PA shields.

4.2. *Modified mode of TBI application*

Several improvements in our Radiotherapy Department equipment, which took place in 2009, resulted in the modification of the TBI irradiation technique, because our accelerators had

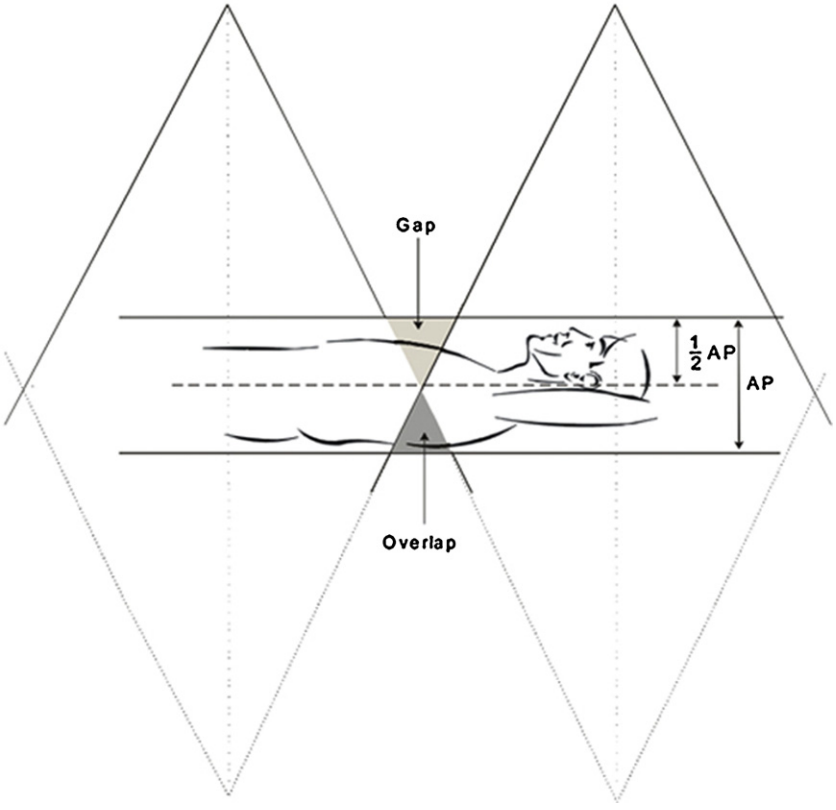


Fig. 2 – Illustration of AP/PA fractions and fields junction region.

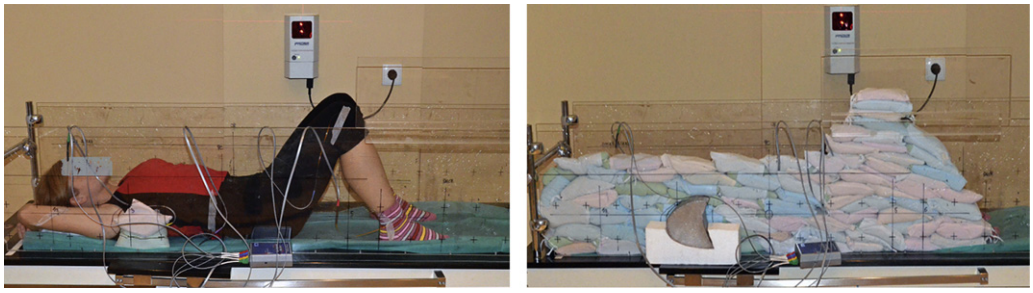


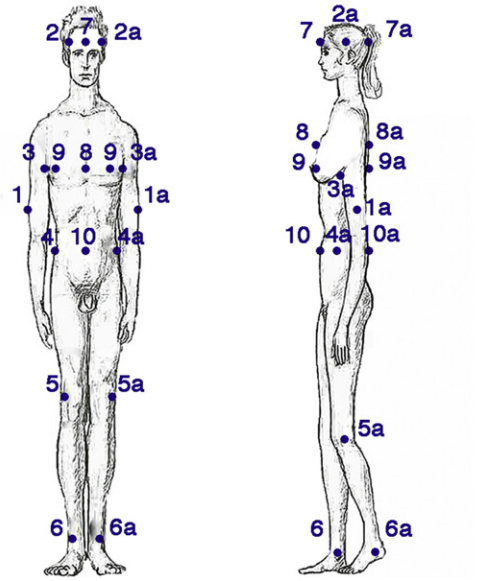
Fig. 3 – Rice bags as a bolus material.

Table 2 – Distribution of cases treated with modified TBI technique.

Diagnosis	Number of cases
Leucemia limphoblastica acuta (ALL + CML)	26
Lymphoma malignum (NHL)	21
Lymphogranulomatosis malignum (LGM)	3
Total	50

been furnished with additional devices, like portal and orto-voltage imaging, improving standard techniques. Therefore, practical application of TBI required to adapt the method to technical possibilities of accelerators. Changes in the accelerator equipment made the AP/PA fractions more complicated to realize in such geometric conditions. Since January 2010, our patients have been treated with a modified technique, which is easier and less time consuming. Fifty patients (aged 5–60) have already been irradiated according to the modified schedule with the prescribed dose of 12 Gy to PC point (Table 2).

According to the modified protocol, treatment was carried out with 15 MV photon beam in six lateral fractions only (SSD = 330 cm field 40 cm × 40 cm at the distance of 100 cm, dose-rate 6.5 cGy/min), two fractions a day for three consecutive days. For the use of this technique, the radiation oncologists decided to deliver the dose to the mediastinum and lungs area equal to 10 Gy which is essential for therapy. Therefore, a lateral lung shield was used for a part time of the total irradiation. In certain reasonable cases, the radiation oncologists decided not to use the lung shields and then the lungs and mediastinum region were irradiated with full dose of 12 Gy. Reports can be found in available literature[20] where doses of 10 Gy or even 11 Gy were delivered to the lung tissue, and well tolerated with no complications after radiotherapy. The time of lungs shielding to decrease the dose to 10 Gy is calculated, and closely depends on an individual patient's anatomy. Correctness of an individual shield positioning before the first fraction was checked by an X-ray film. After checking the shield location correctness, the shield shape was traced on the frame plexiglas wall (see Fig. 3), and it could be used for the next shielded fractions. The underdosage in the lateral chest wall region was supplemented to the dose of 12 Gy by electron beams of the nominal energy from 6 MeV to 12 MeV. The shape of an electron irradiation field is an aperture of photon shield and is mapped from treatment planning system (TPS).



Point's number	Place on the patient's body
1	Right side of the arm (1/2 AP)
1a	Left side of the arm (1/2 AP)
2	Right side of the head (temple ½ AP)
2a	Left side of the head (temple ½ AP)
3	Right side of the chest (temple ½ AP)
3a	Left side of the chest (temple ½ AP)
4	Patient's right side in the middle of beam (PC, ½ AP)
4a	Patient's left side in the middle of beam (PC, ½ AP)
5	Knee (right side)
5a	Knee (left side)
6	Foot (ankle joint) right side
6a	Foot (ankle joint) left side
7	Forehead
7a	Back of head
8	Top of chest
8a	Back of chest
9	Top of chest under the lung shield
9a	Back of the chest under the lung shield
10	Point on the abdomen in the middle of patient's length (PC)
10a	Point on the back in the middle of patient's length (PC)

Fig. 4 – Localization of points for which the doses are calculated and measured.

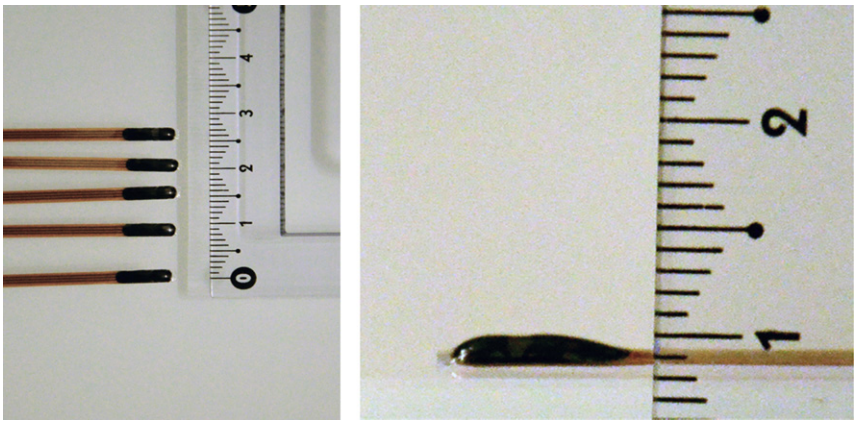


Fig. 5 – Metal-oxide semiconductor field effect transistor (MOSFET) detectors.

4.3. *Dose distribution verification*

To investigate the homogeneity of dose distribution in the entire body of the patient, 20 measurement points were designated (Fig. 4) and for these points the doses were calculated and then measured. The prescribed dose to PC point was 12 Gy.

Dose verification measurements were performed by the use of miniature Metal-Oxide Semiconductor Field Effect Transistor (MOSFET) detectors (see Fig. 5) with detector active volume less than 1 mm^3. Parameters of these detectors have been described in papers.[35,36] Their measurements accuracy is 2.2% (1SD).

On introduction of this method, the Farmer type 0.6cc ionization chamber was used for a double check of the dose in PC point. Since the difference between both readings (MOSFET and Farmer) was negligible (less than 2%), the double check was abandoned and MOSFET established as a chosen technique for TBI in vivo dosimetry.

Additionally, the problem of very small dimensions of MOSFETS detectors requires special solution for electron fields applied as the boost for the chest wall. To ensure electron equilibrium within the area of measurement, the detectors were placed in specially designed aluminium capsules.[36]

5. Results and discussion

The percent difference between measured and calculated dose to PC point was determined at each of the 20 points for patients in both groups. The results are presented in Figs. 6 and 7. It can be observed that, taking into account all results, the mean percent difference between the measured and planned dose to PC point is 6.4% (SD = 4.7%) and 7.9% (SD = 6.4%) for the initial TBI technique and the modified one, respectively.

The results presented in Table 3 show the mean percentage differences between measured dose in individual points, taking into account all patients in a particular group.

The modified TBI technique allows to achieve the expected homogenous dose in the points of interest similar to those obtained with the initial irradiation protocol. The calculated and measured doses in most cases met the range of 11.4–14 Gy (95–116% of the dose of 12 Gy planned to PC point), which was a required result (see Fig. 7).

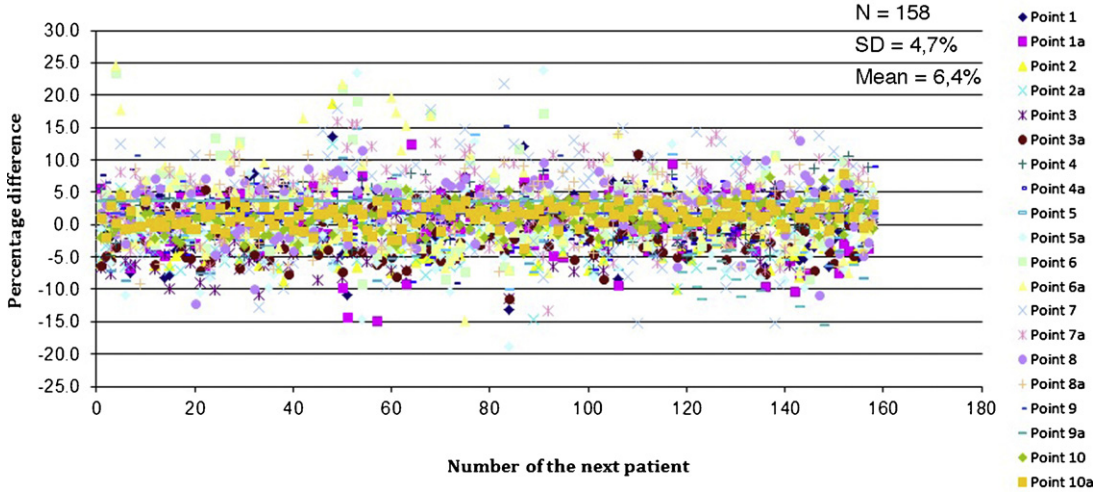


Fig. 6 – The values of percent difference between the measured and planned dose to PC = 12 Gy for all anatomical point of patient treated with the initial TBI technique.

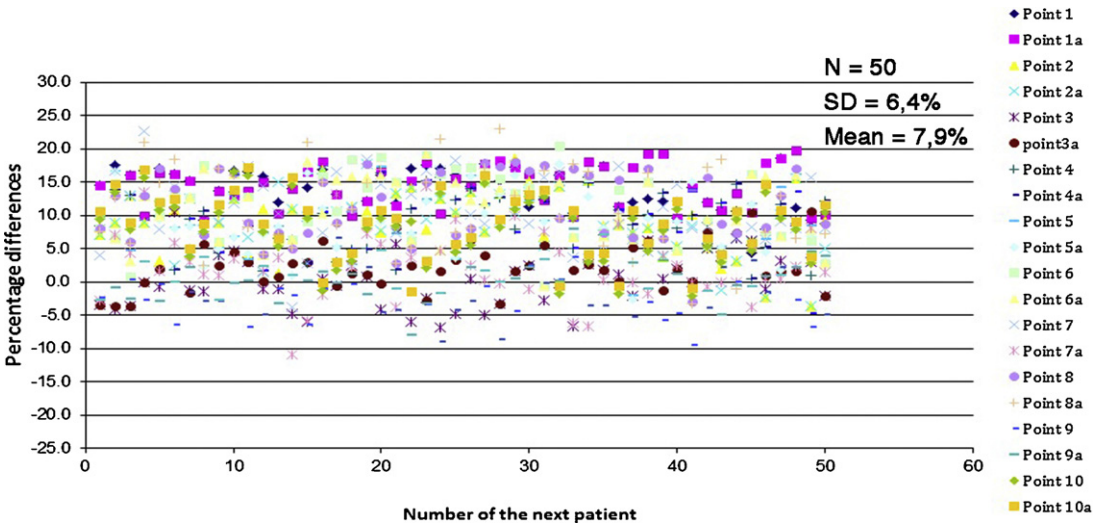


Fig. 7 – The values of percent difference between the measured and planned dose to PC = 12 Gy for all anatomical point of patient treated with the modified TBI technique.

The distribution of doses for all patients and for all points presented on the graphs (Figs. 6 and 7) and in Table 3 is in most cases contained within the range from −5% to 16% for both analyzed groups of patients. The greatest inhomogeneity of dose distribution appears in the chest area. It is caused by the tissue diversity and the shielding used in this area. However, our intention was to reduce the dose in the lungs.

Fig. 8 shows a graphical representation of dose distribution in the chest area for the case of using the initial TBI technique with the AP/PA fields, lateral fields and electron boosts for the chest wall.

The same case with a graphical representation of dose distribution in the chest area planned for the modified TBI technique is shown in Fig. 9. In this case, the TBI irradiation technique consisted only of lateral fields and lateral electron boosts for the chest wall. It can be seen that in comparison with the initial TBI protocol, the dose in the mediastinum is lower while the dose in lungs is slightly higher.

Therefore, we are considering to use the technique of dynamic photon irradiation in the chest area which allows to increase the dose to the mediastinum while sparing lung tissue. For this purpose, patient should be exposed to a lateral radiation in six fractions, like so far, and their whole chest region shielded with a block. Then the dose will be delivered as a VMAT plan in 2 or 3 fractions. Fig. 10 shows a graphical simulation of dose distribution in the chest area, prepared in

Table 3 – Percentage difference between the measured and planned dose to PC for individual points.

Point number	N = 158 patients		N = 50 patients	
	%SD	%Mean diff.	%SD	%Mean diff.
1	5.2	8.8	3.1	13.7
1a	5.3	8.2	3.1	14.4
2	4.2	5.6	4.6	9.2
2a	4.5	5.4	4.7	9.1
3	4.4	2.6	4.0	0.2
3a	3.8	2.9	3.7	2.5
4	4.0	7.4	4.3	9.3
4a	4.0	2.7	4.7	9.3
5	4.8	6.0	4.5	9.2
5a	5.3	5.9	4.7	8.9
6	5.3	7.8	5.4	10.7
6a	5.8	7.9	5.1	10.5
7	5.7	7.4	5.3	10.6
7a	4.3	8.9	5.2	2.5
8	3.4	6.3	5.1	11.0
8a	4.1	6.4	6.2	11.0
9	3.3	5.3	4.2	2.1
9a	4.1	8.4	2.9	0.6
10	2.1	4.4	4.7	7.9
10a	1.7	4.9	4.8	8.7
Total	4.3	6.4	4.5	7.9

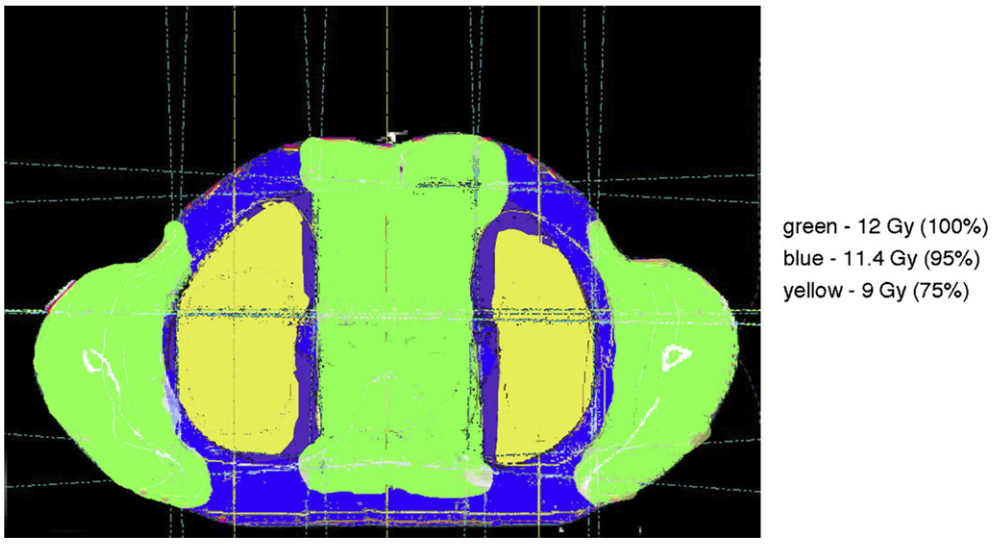


Fig. 8 – Dose distribution in chest region – a sum of two AP/PA fractions with electron boosts and four lateral fractions – planned dose to PC was 12 Gy.

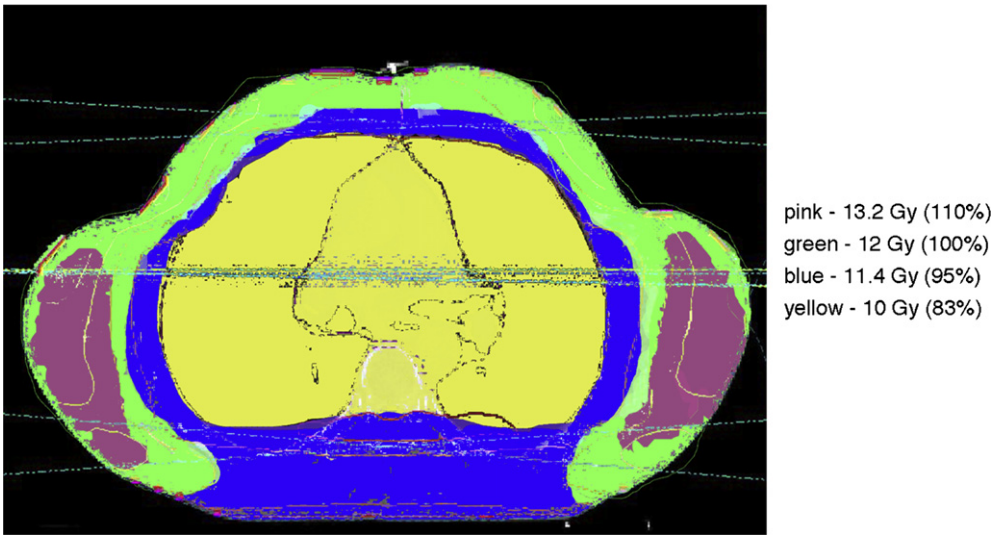


Fig. 9 – Dose distribution in chest region – 6 lateral fraction with lateral electron boost.

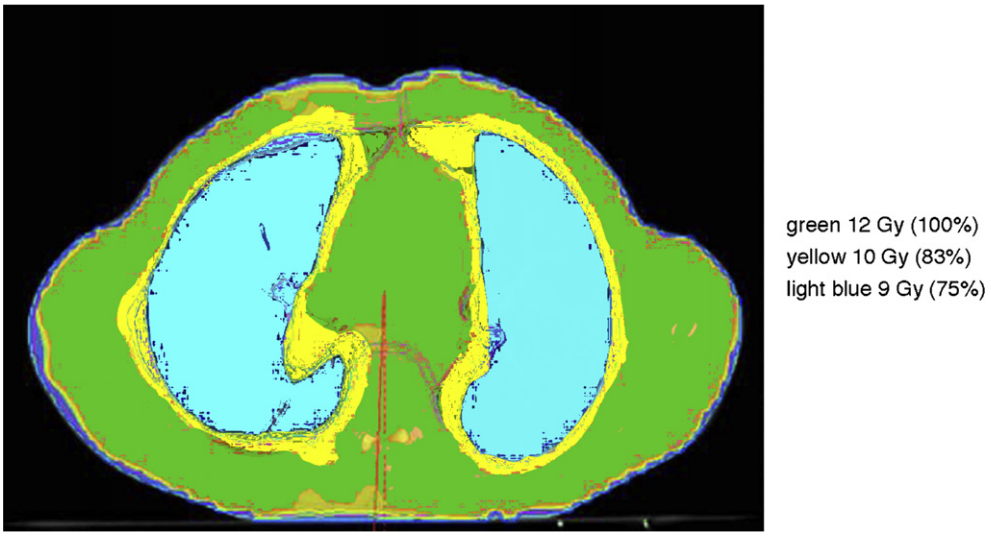


Fig. 10 – VMAT as an advanced solution for dose distribution in chest with mediastinum region.

the Monaco treatment planning system as a dynamic VMAT plan.

6. Conclusions

In conclusion, it can be pointed out that in general (except few points) differences between the planned and measured doses in relation to PC point are contained between −5% to +16% (excluding the chest area). Both presented TBI techniques allow to achieve the assumed dose distribution.

On the basis of prepared simulations for the VMAT technique, without electron boosts, we can state, that this solution seems to be an advanced technique for our TBI method, especially for lungs area. However, further research of this solution is required in our Radiotherapy Department.

Conflict of interest

In the past, authors hadn't any sponsored research agreement in this topic.

Financial disclosure

None declared.

REFERENCES

1. Gilson D, Taylor RE. Total Body Irradiation. Report on a Meeting Organized by the BIR Oncology Committee, Held at The Royal Institute of British Architects London, 28 November 1996. *Br J Radiol* 1997;**70**:1201–3.
2. Bieri S. Total body irradiation before allogeneic bone marrow transplantation: is more dose better? *Int J Rad Oncol Biol Phys* 2001;**49**:1071–7.
3. Hagenbart U. Treatment for acute myelogenous leukemia by low-dose, total-body, irradiation-based conditioning and hematopoietic cell transplantation from related and unrelated donors. *J Clin Oncol* 2006;**24**:444–53.
4. Quast U. Total body irradiation – review of treatment techniques in Europe. *Radiother Oncol* 1987;**9**:91–106.
5. Barret A. Total body irradiation. *Rep Prac Oncol Radiother* 1999;**4**(3):47–63.
6. Shank B. Techniques of magna-field irradiation. *Int J Radiat Oncol Biol Phys* 1999;**42**:1925–31.
7. Connor S, Scrimger J, Logus W, Johnson L, Scharther E. Development of translating bed for total body irradiation. *Med Dosim* 1988;**13**(195):199.
8. Jensen JM, Hebbinghaus D, Schneider R. *SIMRT in practice: 18 years of experience in TBI*. University of Kiel Medical School; 2001.
9. Bradley J, Reft C, Goldman S, et al. High-energy total body irradiation as preparation for bone marrow transplantation in leukemia patients: treatment technique and related complications. *Int J Radiat Oncol Biol Phys* 1998;**40**:391–6.
10. Leer JWH, Broerse JJ, Vroome H, Chin A, Noordijk EM, Dutreix A. Techniques applied for total body irradiation. *Radiother Oncol* 1990;(Suppl. 1):10–5.
11. Thiti S, Puangtong K, Puangpen T, Chirapha T, Tasanee L, Orawan R. *In vivo* whole body dosimetry measurement technique of total body irradiation: a 12-year retrospective study result from one institute in Thailand. *J Med Assoc Thai* 2011;**94**(6):732–7.
12. Quast U. Whole body radiotherapy: a TBI-guideline. *J Med Phys* 2006;**31**:5–12.
13. Podgorsak EB, Podgorsak MB. Special procedures and techniques radiotherapy. In: Podgorsak EB, editor. *Radiation oncology physics: a handbook for teachers and students*. Vienna: International Atomic Energy Agency; 2005. p. 123–59.
14. Kirby TH, Hanson WF, Cates DA. Verification of total body irradiation dosimetry techniques. *Med Phys* 1988;**15**:364–9.
15. Van Dyk J, Galvin JM, Glasgow GP, et al. The physical aspect of total and half body photon irradiation. A report of AAPM No. 17, 1986.
16. Barret A. Total body irradiation before bone marrow transplantation: a review. *Clin Radiol* 1982;**33**:131–5.
17. Malicki J. The accuracy of dose determination during total body irradiation. *Strahlenther Onkol* 1999;**175**:208–12.
18. Aydogan B, Mundt AJ, Roeske JC. Linac-based intensity modulated total marrow irradiation (IM-TMI) technology in cancer research and treatment. *Technol Cancer Res Treat* 2006;**5**(5.).
19. Mehrdad S, Cedric Y, Chen DJ, Leon Der. A translational couch technique for total body irradiation. *J Appl Clin Med Phys* 2002;**2**(4):201–9.
20. Skowrońska-Gardas A. Assessment of early results and complications after total body irradiation (TBI) using home-made modification. *Nowotwory – J Oncol* 2006;**5**(2):179–84 [in Polish].
21. Malicki J, Kierzkowski J, Kosicka Giwsp. Calculation and measurement verification of dose distributions in patient subjected to fractionated total body irradiation. *Nowotwory – J Oncol* 1995;**45**:39–45 [in Polish].
22. Malicki J, Wachowiak J, Kosicka Giwsp. Dose distributions and early treatment results in patients with acute leukaemia subjected to fractionated total body irradiation before allogenic bone marrow transplantation. *Nowotwory – J Oncol* 1996;**46**:731–6 [in Polish].
23. Malicki J, Skrobała A, Kosicka G, Wachowiak J. The efficacy and reliability of lung protection during total body irradiation of patients with disseminated malignancies. *Neoplasma* 2005;**52**:325–9.
24. Malicki J, Kosicka G, Stryczyńska G, Wachowiak J. Kobalt 60 versus 15 MeV photons during total body irradiation: doses in the critical organs and complexicity of the procedure. *Ann Transplant* 2001;**6**:18–22.
25. Ryczkowski A, Piotrowski T. Tomotherapy archive structure and new software tool for loading and advanced analysis of data contained in it. *Rep Pract Oncol Radiother* 2011;**16**(2): 58–64.
26. Zhuang T. Generating arbitrary one-dimensional dose profiles using rotational therapy. *Phys Med Biol* 2010;**55**(20):6263–77.
27. Penagaricano JA, Chao M, Van Rhee F, et al. Clinical feasibility of TBI with helical tomotherapy. *Bone Marrow Transplant* 2011;**46**:929–35.
28. Susanta K Huib, Jeff K, Jack F, et al. Feasibility study of helical tomotherapy for total body or total marrow irradiation. *Med Phys* 2005;**32**:3214–24.
29. Schultheiss E, Liu A, Olivera G, Kapatoes J, Wong: J. Total marrow and total lymphatic irradiation with helical tomotherapy. *Med Phys* 2004;**31**:1845.
30. Piotrowski T, Adamska K, Malicki J. Effect of scattered radiation in the total body irradiation technique: evaluation of the spoiler and wall dose component in the depth dose distribution. *Nukleonika* 2007;**52**(4):153–8.
31. Sroka M, Reguła J, Łobodziec W. The influence of the bolus-surface distance on the dose distribution in the build-up region. *Rep Pract Oncol Radiother* 2010;**15**:161–4.
32. Kassae A, Xiao Y, Bloch P, Goldewin J, Rosenthal DJ, Bjarngard BE. Doses near the surface during Total Body Irradiation with

15 MV X-rays. *Int J Cancer (Radiat Oncol Invest)* 2001;(Suppl. 96):125–30.
33. Kawa-Iwanicka A, Łobodziec W, Iwanicki T, Dybek M, Gawelko J, Czerwinska D. Dose uniformity in the total body irradiation technique using 15 MV photon beam. *Phys Med* 2004;**20**(Suppl. 1):144–6.
34. Kawa-Iwanicka A, Dybek M, Iwanicki T, Łobodziec W, Radkowski A. The technique of Total Body Irradiation applied in the S. Leszczyński Memorial Hospital in Katowice. *Rep Pract Oncol Radiother* 2002;**7**:53–60.
35. Dybek M, Łobodziec W, Kawa-Iwanicka A, Iwanicki T. MOSFET detectors as a tool for the verification of therapeutic doses of electron beams in radiotherapy. *Rep Pract Oncol Radiother* 2005;**10**(6):301–6.
36. Dybek M, Łobodziec W, Kawa-Iwanicka A, Iwanicki T. MOSFET detectors as a tool to verify the doses in photon beam radiotherapy. *Rep Pract Oncol Radiother* 2003;**8**(Suppl. 2): 2074.