sIMRT in daily routine - cfTBI.*

J. M. Jensen, D. Hebbinghaus,
R. Schneider, B. Kimmig

Dept. of Radiooncology,
University of Kiel Medical School, Kiel, Germany

Abstract

In 1983 our department started to perform total body irradiation (TBI) in a special manner. To realize a homogeneous dose distribution within the entire body we used individual hemibody compensators to deliver 12 Gy within 6 fractions, excluding parts of the lungs, which received 11 Gy accomplished by an integrated lung block. Taking into consideration the geometrical settings and possibilities, radiobiological sights and the comfort of the patient we decided for a bilateral-opposing field technique. For application of 12 Gy and 11 Gy for the lung respectively, it takes an overall treatment time of about 25 min per fraction (beam-on time; positioning of patient and compensator; verification). The mean actual dose rate ($\approx$ 12 cGy/min) is mainly set by the primary dose rate of the treatment unit, the focal-spot-midplane-distance and the lateral diameter of the patient.

This early technique was called compensated fractionated total body irradiation (cfTBI) or nowadays, in a more fashionable term, sIMRT (static intensity modulated radiotherapy).

The fluence matrix is calculated on the basis of a series of CT-scans, geometrical and beam data, and subsequently transferred to an automatically working 3D-cutting and milling machine. For compensating of missing tissue and density imhomogeneities an appropriate material is used. Several QA-tests are done before treating the patient.

By changing the compensating material this sIMRT-system is also applicable to standard IMRT, based on inverse planning, but with increased spatial and dosimetrical resolution because of non-MLC technique.

Key words: Total body irradiation, compensators, intensity modulation

---

* Presented at 1st Asia Oceania Congress of Medical Physics, Bangkok, 16-18 Nov. 2001

Introduction.

In 1983 our department started to perform total body irradiation (TBI) prior to bone marrow transplantation (BMT) as a preconditioning regimen in leukemic diseases [1]. One of the main tasks of radiotherapy in general and in this specific case is to realize a homogeneous dose distribution within the entire body to devitalize bone marrow and to minimize immune reactions and various side effects after BMT [2, 3]. The total dose is set to a well defined value and a fractionation course is chosen not expecting serious radiation induced side effects.

Method.

To realize the above mentioned aims a set of CT-scans ($\approx$ 80 slices) is used to take into consideration patients contour, inhomogeneities and geometrical settings for calculating and producing two hemibody compensators. For the comfort of the patient during treatment a bilateral-opposing field technique in a supine position is used. A 15 MV Photon (15MeV-X) beam of a linear accelerator is used to create a homogeneous dose distribution along longitudinal axis of the patient. To avoid the strong photon build-up effect a 2 cm lucite beam spoiler is placed close to the patient's skin to raise surface dose. The influence of variable lateral diameter of patient is compensated for by an individual hemibody compensator. Several parameters [4, 5] are taken into account depth of midplane, specific absorption coefficient of compensating material and geometric parameters. For lung dose reduction from 12 Gy to 11 Gy an individual block is implemented into both compensators. This irradiation technique was called "compensated fractionated total body irradiation" because the total dose is delivered in 6 fractions within 3 days by an actual midplane dose rate of 12-15 cGy/min.

The primary dose rate of 300 cGy/min is reduced by focus-midplane-distance (390 cm) and spatially modulated by the individually calculated compensator to accomplish constant dose rates within the midplane of the patient. The reference point for modulation is the place quoted maximum radiological depth or minimum dose rate respectively.

The maximum cutting depth in styrofoam for producing moulds is 7.5 cm or taking into account the compensating material a modulation value of −75 %.

For modulation and field shaping an appropriate material is necessary which allows dose rate reduction of at least 95 %. The practical application of an reusable material is under investigation.

This technique allows to modulate the beam within the whole treatment field simultaneously compared to recently introduced multileaf-collimator (MLC)-techniques, such as step and shoot or dynamic IMRT.

The characteristics of this dose modulation by compensators forms the term sIMRT (static intensity modulated radiotherapy) [6, 7]. The cutting depth for mould production is calculated on the basis of CT-scans, geometrical and beam data according to relative fluence information. The spatial resolution, Sx, depends mainly on cutting tool, the dosimetrical resolution, Sd, depends on the diameter of Sn-granules embedded in paraffin used as compensating material and on cutting accuracy (Sx $\approx$ 0.4 x 2 cm^2, Sd $\approx$ 1 %). Production of moulds is done automatically by a computer-controlled 3D-cutting and milling machine (HEK, Lübeck, Germany). In contrast to MLC-based IMRT this technique allows high spatial and dosimetrical resolution and subsequently extremely smooth dose distribution.

Results.

Before treating patients several QA-checks are done but just once on each compensator. These procedure are radiography, measurement of relative dose distribution, transmission measurement, dosimetry of absolute dose values and calculation of dose for reference points. During treatment the position of patient is controlled by verification films and the dose is checked by in-vivo-measurements with an ionisation chamber within the midplane: $\Delta D \approx \pm 3.5\%$; $\Delta x \approx \pm 1$ cm. These quality assurance steps show an excellent coincidence between planning and realization of treatment.

As stated primarily this sIMRT-technique for cfTBI should result in a low side effect. The evaluation of the patient data proved this assumption. The acute side-effects (selection) have been investigated within the whole patient group,

***Table I* Acute side effect**

Acute side effect	Percent
mucositis (gr. 1–2)	32.4
mucositis (gr. 3–4)	31.6
fever	10.9
nausea	47.5
nausea incl. vomiting	28.6
GvHD (skin, gr. 1 - 4)	21.2

and within the surviving group the following late and chronic side-effects (selection) have been observed:

***Table II* Chronic side effect**

Chronic side effect	Percent
cataract	3.4
cataract (children)	37.0
bone necrosis	5.2
cGvHD	18.2
interst. pneumonia	4.7
CMV ass. pn.	3.7
organ malfunctions	9.9

Conclusions for the future.

As mentioned above this sIMRT-technique is also applicable to standard IMRT based on inverse planning and conversion of fluence matrices into MLC-settings or movements. The advantages of sIMRT are obvious. The advantages are higher spatial and dosimetrical resolution, shorter beam-on-time as well as total treatment time also when compensators are changed manually (which is depicted as an anachronism in our computerized world) applicable also on non-MLC-treatment units (Cobalt-60-units) simpler quality assurance tests and no treatment unit interference during production of compensators. Beside these draw backs of MLC-based treatments there is another striking disadvantage. In most TBI-modalities the patient is lying along the diagonal of the field, therefore the technically limited overtravel of the MLCs prevents it's usability in TBI.

All non-sIMRT-techniques show the disadvantage of lack of information about dose distribution within the 3D-volume. There is no fixed connection between dose points as it is realized in wedged fields or sIMRT-fields. A compensator is nothing special than a specific multi-dimensional wedge. Handling of sIMRT can be speeded up by simple automatic change of compensators. Hereby treatment times are reduced down to standard values (5-field-technique, 2 Gy $\approx$ 5-8 min) as well as beam-on-times ($\approx$ 2.5 min) which might be a positive aspect in radiation protection. And last but not least, practice shows that down-time of a linear accelerator is outvoted by MLC-faults.

In contrast to computer-controlled IMRT applications the sIMRT-solution meets one of Albert Einstein's demands. *Make it as simple as possible, but not at all simpler.* ■

References.

1. Jensen JM, Brix F, Hebbinghaus D : *The Kiel Model of total body irradiation–Technical and dosimetric aspects.* Proc. Varian 4th European Clinac Users Meeting, Malta, May 25-26, 1984
2. Jensen JM, Schneider R, Schultze J, Schmitz N, Kovacs G, Kimmig BN : *Total body irradiation using compensators–13 years of experience.* ICRO'97, Beijing, In: Radiother. Onc.43 (Suppl. 2), p.10/Abstr. No.42, 1997
3. Jensen JM, Hebbinghaus D, Schneider R : *sIMRT in practice: 18 years of experience in TBI.* ICRO'01, Melbourne, In: Radiother. Onc.53 (Suppl.1), p. 46/ Abstr.No.165, 2001
4. Jensen M, Brix F, Kohr P: *General and specific aspects of experimental dose measurement in total body irradiation (TBI).* Strahlenther. Onkol. 162, 250-253, 1986
5. Kohr P, Jensen JM : *Some remarks on method and dosimetry of the Kiel compensating system.* Strahlenther. Onkol. 163, 228-230, 1987

6. Jensen JM, Hebbinghaus D: *Some remarks on IMRT: Static vs. dynamic vs. step &shoot. Where is the realistic future in practice?* Proc. IMRT2k: 1. Int. Workshop on IMRT, Brussels, 3-5 June, 2000
7. Jensen JM, Hebbinghaus, D: *Some remarks on IMRT: Static vs. dynamic vs. step&shoot. Where is the realistic future in practice?* ICRO'01, Melbourne, In: Radiother. Onc. 53 (Suppl. 1), p. 8/Abstr. No. 27, 2001