case report

Missing tissue compensation with wax filter compensators in radiotherapy of the head and neck region

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Background. *In the conventional radiotherapy of the head and neck region, the inhomogeneity of the absorbed dose in certain clinical situations can exceed ? 5% of the nominal dose. Depending on the pattern of dose inhomogeneity, treatment related toxicity is more pronounced and disease control reduced. The aim of our report is to present the wax filter compensation technique used in our department.*

Case report. *A 46-year-old male with inoperable carcinoma of the oropharynx of clinical stage T3N2c was irradiated with 5 MV linear accelerator photon beams and conventional 3-field technique. In order to obtain more homogenous dose distribution in treated volume, the opposed lateral fields were modified using 2D-wax filter compensators.*

Results. *Using conventional wedge filter compensation, the planed absorbed dose deviations in the treated volume were in the range of 94% to 113% of the prescribed dose. By modification of the opposed lateral fields with 2D wax filter compensators, the variations of the absorbed dose were reduced to the range from 93% to 105% of the prescribed dose. In the article, the planning and manufacturing as well as dosimetric checking of wax filter compensators are described.*

Conclusions. With the use of 2D wax filter compensators, the inhomogeneity of absorbed dose distribution was significantly reduced, and the quality of treatment considerably improved.

Key words: head and neck neoplasms-radiotherapy; radiotherapy dosage

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Introduction

The conventional teleradiotherapy technique for head and neck tumors consists of two opposing lateral fields, encompassing primary tumor and upper neck lymphatics, and one anterior field to cover the lower neck and supraclavicular regions. To provide a homogenous dose distribution, the most elementary compensation technique is the wedge compensation of lateral fields. Even though, the precalculated variations of the delivered dose inside of the target volume can, in certain cases, highly exceed ± 5 % of the nominal dose as recommended by ICRU.[1,2] The following two factors contribute to the inhomogeneity: *(1)* the difference in the amount of tissue between different levels inside of the head and neck region that is more pronounced in thin patients and after extensive neck surgery ("geese neck"); *(2)* the difference in the tissue structure, i.e. different electronic tissue density of various structures in the head and neck region (bones, soft tissue, air cavities).

Both, the volume and the position of the low/high dose regions, together with the level of variations from the nominal (reference) dose, can significantly compromise the quality of treatment. »Hot spots« result in more pronounced acute side effects of irradiation, which could influence the scheduled radiotherapy course, and consequent late toxicity could importantly decrease the patient's quality of life during post-treatment period. In addition, »cold spots« reduce the probability for controlling the disease and, therefore, the patient's chance for cure.

When absorbed dose inhomogeneities in the treated region are considered to be unacceptable, the need for more sophisticated compensational technique emerges.[3] The compensation technique should be chosen according to the individual clinical situation and technical and logistic possibilities in particular radiotherapy department. When the full skin-sparing effect of megavoltage treatment beam is desirable, the use of filter compensators is indicated.[4]

The filter compensator material is chosen according to the electron density of the material and according to the quality of irradiating beam.[5] The filter compensator material should also not significantly change the beam quality.[6] Several studies showed that wax can be successfully used as a material for filter compensators.[5] The required dose reductions for compensating purposes are usually up to 20 %. For 5 MV photon beam that is achieved using approximately around 5 cm of wax.

The aim of our report is to present the wax filter compensation technique used in our department.

Case report

A 46-year-old male with inoperable carcinoma of the oropharynx of clinical stage T3N2c was referred to the Department of Radiotherapy at the Institute of Oncology Ljubljana, Slovenia, for curative treatment with radiotherapy. The patient was simulated on conventional simulator with CT option (Philips SLS-CT). Irradiation technique consisted of two opposed lateral fields (270° and 90°: 11.5 cm × 13.5 cm) to cower the region of primary tumor and upper neck lymphatic basins, and one anterior field (0°: 21 cm × 9 cm) to cower lower neck and supraclavicular regions. The parts of the fields to be spared of

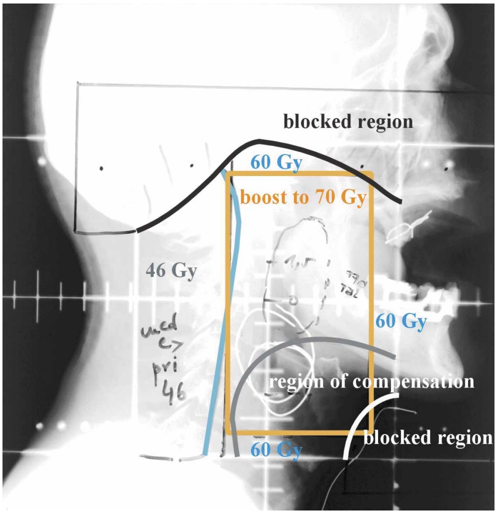

Figure 1. The simulator film of the right lateral field (270į). The positions of the CT images are indicated (central slice, through the isocenter; upper slice, 1.5 cm above the isocenter; lower slice, 4 cm below the isocenter). The blocked regions and the high dose region that should be compensated are delineated. The three phases of the photon treatment are indicated: the whole treatment volume up to 46 Gy, avoiding medulla from 46 to 60 Gy and boost to gross disease from 60 to 70 Gy.

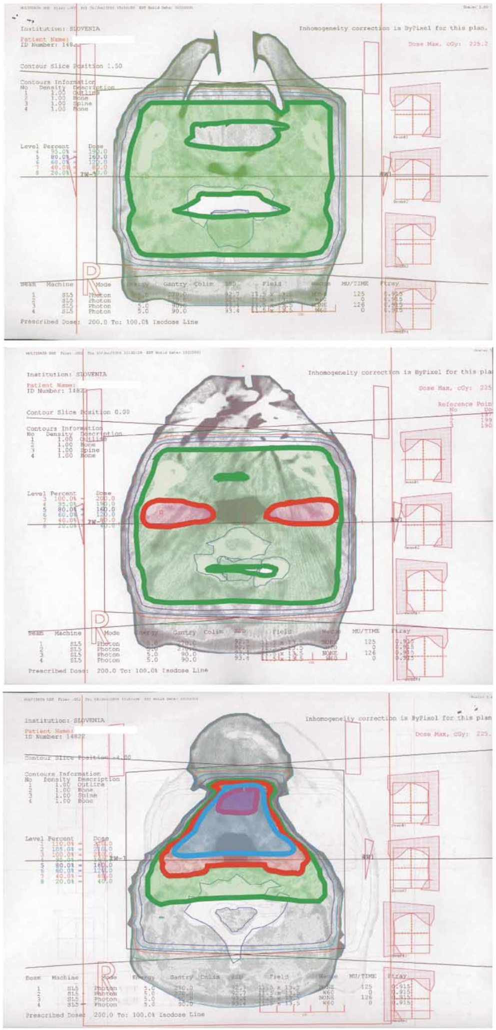

Figure 2. The optimized dose distribution was calculated using three CT slices (see Fig. 1). Applying only wedge filter compensators, the calculated inhomogenieties inside the treated volume were significant. The regions of different absorbed doses, expressed in the percentage of prescribed dose, are colored: 95 % ≤ green <100 %; 100 % ≤ red <105 %, 105 % ≤ blue <110 %, 110 % ≤ purple < 115 %. On the central slice (through isocenter), the dose varied from 95% to 100% of prescribed dose.
On the lower slice (4 cm below isocenter), the absorbed dose exceeded 110% of the prescribed dose. On the upper slice (1.5 cm above isocenter), the absorbed dose hardly reached 95 % of the prescribed dose. The planed overall inhomogeniety range applying only wedge filter compensators was 19 % of the prescribed dose.

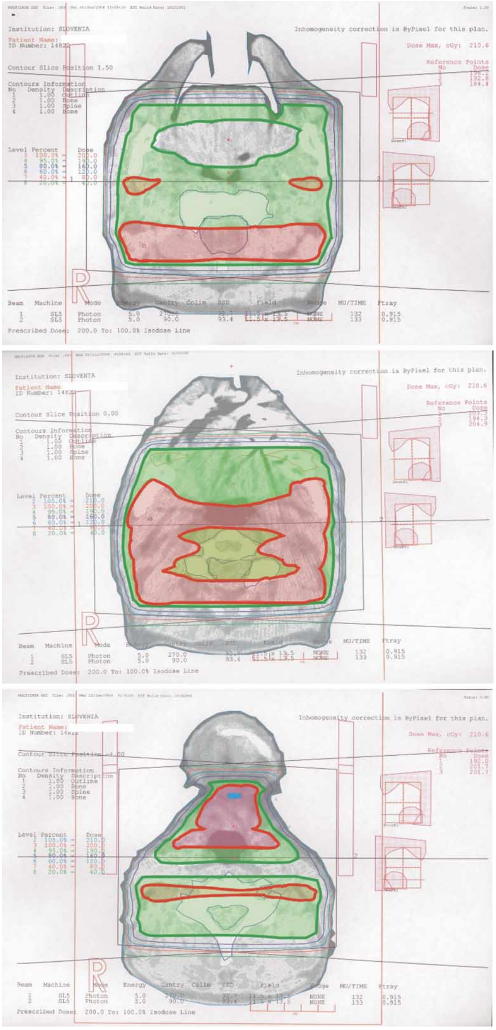

Figure 3. Applying the 2D paraffin wax filter compensator, the optimized dose distribution was calculated. In the high-dose region, the filter compensator was introduced as a block of 85% transmission. Dose distribution is presented on the same slice levels as on Fig.1 (central slice, +1.5 cm, - 4 cm). As the result, the dose distribution is much more homogenous as it was applying only wedge filter compensators (Fig.2). At the central slice, the absorbed dose is almost homogenous (100% of the prescribed dose), at the lower slice, the maximum dose hardly reaches the 105%, and it ranges from 93% to 100% of the prescribed dose on the upper slice.

irradiation were delineated on simulator film. The three CT slices were taken at three different levels: central slice (through isocenter); upper slice, 1.5 cm above the isocenter; lower slice, 4 cm below the isocenter (Figure 1).

The treatment was carried out in three phases. Phase 1: using 5 MV linear accelerator photon beams and 2 Gy daily fractions up to 46 Gy. Phase 2: from 46 Gy to 60 Gy; the lateral fields were shielded in the region of spinal cord which was boosted with 9 MeV electron beams. Phase 3: boost to gross disease to cumulative dose of 70 Gy

The optimal use of wedge filters and the irradiation times for each individual field were calculated with 2D planning algorithm with correction for tissue electron density (Multi-Data DSS, Multidata System International Corp., St. Louis, Missouri, USA). Applying wedge filters only, the planed inhomogeneities inside the treated volume covered with the opposed lateral fields ranged from 94% to 113% of the prescribed dose.

In this particular clinical situation, the degree of dose inhomogeneity (19%) indicated the use of compensator. The bolus type compensator was not suitable because we wished to preserve the skin sparing effect of megavoltage photon beams. Therefore, the use of 2D wax filter compensator was indicated. The region of dose compensation (the »high dose« area) was indicated on the film as shown on Figure 2.

The optimal dose compensation of the high dose region was calculated using the MultiData DSS planning system. The compensated region was introduced into the planning system as a block of a certain transmission T. The optimized transmission of the compensated region was found to be 85%, as shown on Figure 3. With the compensation of high-dose region, we could prolong the irradiation time of each individual opposed lateral field by 5%, thereby also increasing the delivered dose to previously low-dose regions.

Figure 4. The foam blocks with blocking filters made of Wood alloy and filter compensators made of paraffin wax, were manufactured for each of the lateral opposed fields (gantries 270į and 90į). The central hole was drilled in each of the foam block in order to see the center of the optical fields. The positioning holes were drilled in the corners of the blocks. The 30 × 30 × 8 cm3 foam blocks had to be cut to the suitable dimension for Philips SL 75/5 linear accelerator, i.e. to 21 × 30× 8 cm3. The foam blocks were fixed on the positioning trays, ready to use.

The paraffin wax compensator filter assembling technique

The negative cut of the individual blocking filter and the negative cut of the compensator filter were milled in the previously calibrated 8 cm thick foam blocks (block dimensions: 30 cm × 30cm × 8cm) by the computer-guided milling machine (ACD – 5, Par Scientific, Denmark).

For the selected field, both negatives, that of the blocking filter and that of the compensator block, were cut in the same foam block. For the blocking filters, the Wood alloy is used because of its high electronic density. For the same reason, Wood alloy is not suitable as the compensator material. To increase compensating precision, the paraffin wax was used as the compensator material.

The negative cuts of the compensated and blocked regions were separated from each other with thin paper wall. First, the blocking region was filled up with the Wood alloy, and consequently, as soon as the Wood alloy solidified, the region of compensating filter was filled with the liquid paraffin wax.

In order to irradiate at gantry 270° and 90° (opposed lateral fields), the foam blocks with shieldings and compensators were fixed on the holding trays as can be seen on Figure 4. As the largest dimension of the foam blocks fixed on the holding trays, used in irradiation, is 21 × 30 × 9 cm^3, the foam blocks of original dimensions 30 × 30 × 8 cm^3, had to be cut off (the original dimensions just at the end of the positioning holes = 21 cm). The central hole was drilled in the center of the foam, allowing for the center of the irradiating field and the position of the blocks and compensator to be verified.

Figure 5. In vivo dosimetry is performed with the preheated and calibrated LiF:Mg:Ti micro-rod thermo-luminescence dosimeters (TLD - 100). TLD were placed in the tubes, covered with the 1.5 cm thick jelly and fixed on the patient. The delivered dose measured in the centers of the lateral opposed fields were 208 cGy on the left patient side and 197 cGy on the right patient side (104% and 98.5% of the planned dose, respectively). The delivered dose in the center of the compensated region on the left patient side was 189 cGy, 94.5% of the prescribed dose. Without the compensation, the dose absorbed in this region would be in the range from 210 cGy to 220 cGy (from 105% to 110% of the prescribed dose 200 cGy).

Dosimetry

Prior to the irradiation of the patient, the filter compensators were checked by dosimetry of filtered beam. The delivered dose was also measured in vivo during the irradiation.7 For dosimetry checks, the micro-rod thermoluminescence dosimeters LiF:Mg:Ti (TLD 100) were used.[8]

Preheated TLD micro-rods were calibrated with 5 MV photon beam. Two TLDs were placed in the centre of the plastic water block (which simulated the patient's head) and were irradiated with two opposed lateral fields. The beams set-up conditions were the same as planned for the treatment without compensators. The response for the delivered dose of 197 cGy in the center of plastic block was measured.

Next, prior to patient treatment, the plastic water block with calibrated TLDs was irradiated according to the treatment plan, using shields and compensators. With applying compensators, we could increase the overall irradiation time and simultaneously the dose delivered at isocenter. The dose measured at the center of the plastic water block was 200 cGy. As it was the same as planned dose, we agreed that the filter compensator was appropriate for clinical use.

In vivo TL dosimetry was preformed twice during the irradiation. The first *in vivo* measurement was preformed on day 1 of the radiotherapy course. The two TL dosimeters were placed under the 1.5 cm thick jelly bolus in the center axis of each of the two opposed lateral fields. The delivered doses in the center of the irradiation fields were 208 cGy on the left and 197 cGy on the right patient's side (i.e. 104% and 98.5% of the planned dose, respectively).

The second measurement was done in the region of the compensated dose. On the left patient's side, the measured dose in the center of the compensated region was 189 cGy, 94.5% of the prescribed dose. Without the compensation, the dose absorbed in this region would be in the range from 210 cGy to 220 cGy (from 105% to 110% of the prescribed dose 200 cGy). On the right patient's side, the dosimeter was placed too close to the blocked region and revealed the dose in the penumbra region. The in vivo dosimetry of the compensated region is presented on Figure 5.

The dose reduction was measured also with film dosimetry. The portal image conditions (5 monitor units [MU], open field; 3 MU, shielded field) were simulated with the planning system. The portal image was calibrated and used for the dose measurements. The overall delivered dose was in the range of 3% of the planned dose, whereas in the region of the dose lowered by the filter compensator the measured dose did not differ for more than 2 % from the planned dose.

Conclusions

Our method of missing tissue compensation using wax filter compensators proved to be precise enough to meet the expectations in clinical setting. Even though the manufacturing process of wax filter compensators is driven by computer-guided machinery, it is time consuming and should be properly scheduled and planned in advance. Anyhow, the quality of treatment was considerably improved.

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