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REPRODUCIBILITY OF FIELD ALIGNMENT IN RADIATION THERAPY

A large-scale clinical experience

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Abstract

A specially designed cassette which gives an excellent quality of portal films has been used to determine the set-up accuracy and uncertainties in treatment alignment during full-course radiation therapy on patients treated for some common malignant diseases. An analysis of a comparison between simulator films and portal films is also presented. For various diagnoses treatment-to-treatment positioning varied with an average standard deviation of 3.5 mm despite the use of laser alignment and good patient fixation.

Key words: Radiation therapy, quality control, patient positioning, localization uncertainties, portal films.

A small change in absorbed dose can give rise to a wide diversity in tumour control and complication probabilities. This especially concerns patients to whom treatment is given with curative intent and when the intended total doses are close to the tolerance of normal tissues. In such cases it is important to deliver the prescribed absorbed dose to the target volume and at the same time to rescue adjacent normal tissue or critical organs. In fractionated treatment, precision must be maintained and controlled throughout the whole treatment course.

Portal films have been routinely used at Radiumhemmet since 1970 (1) to verify that the intended target volume is treated. A low-weight cassette, which is easy to handle and to use and which contains a film that can be developed under the same conditions as diagnostic films, affords easy and accurate control of the set-up and of the day-to-day reproducibility of treatment field alignment. This type of analysis was introduced by Marks et al. (2–4) in a retrospective review of portal films. More recently, additional results have been published concerning accuracy of radiation field alignment when using portal films weekly or daily (5–8). The purpose of the present study was to determine the set-up accuracy and the uncertainties in treatment machine alignment at our department during full-course radiation therapy of patients with some common malignant diseases.

Material and Methods

The simulator room and all treatment rooms at Radiumhemmet are equipped with a midline laser to align the patients on the longitudinal axis of the beam. Opposing lateral lasers are used for horizontal alignment. A Rando phantom was used to determine the magnitude of a change in field alignment that could be detected on a portal film when exposed with ^{60}Co gamma radiation and 4, 6, 8 and 21 MV x-rays. In addition the phantom was used to compare the field alignment of the simulator with that of the different electron accelerators and the ^{60}Co unit. This was performed by comparing the portal film with the corresponding simulator film.

Daily portal films were taken in 35 patients with different diagnoses (Table) and the portal films were compared with the corresponding simulator films. Each treatment unit had no more than 2 patients per day participating in the trial, so as not to interfere too much with routine work. Two patients refused to participate in the study. Most portal films were exposed only a short time (a few seconds) during the treatment session. For comparison some films were exposed for the whole treatment session. The portal films used at the ^{60}Co unit were always exposed for the whole treatment session.

The analysis of the portal films proceeded as reported

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Table

Summary of the results of treatment to treatment variations in daily studies for various diagnoses

Site	Number of patients	Customized blocks	Standard blocks	Number of portal films	Number of measurements per field	Minimum and maximum deviation mm	Average standard deviation mm
Pituitary gland	5			106	2–4	1–5	3
Brain	1	2		26	4	2–4	3
Head and neck	10	2	5	168	4–6	3–6	4
Lung	2			15	4	1–4	3
Breast	5		10	67	3–6	3–7	5
Hodgkin (mantle)	1	1		15	6	2–4	3
Oesophagus	4			110	3–6	3–9	6
Kidney	1			24	3–4	3–6	4
Prostate	2			67	4–6	3–6	4
Ovarium	4	3	6	44	4–6	3–7	5

by Rabinowitz et al. (8). For each field a number of anatomic landmarks were identified, selected for visibility and stability according to clinical relevance. The same landmarks were used when simulator films and portal films were compared. Fig. 1 shows an example of how the measurements were performed. For each portal film we measured the difference in distance between defined points on the portal film and the simulator film. The Table summarizes the number of patients, number of portal films and number of measurements for each field. The mean of all standard deviations of the misalignments and the range are inserted in the Table.

The Rando phantom was used at the simulator and the electron accelerator to simulate the high precision technique used at Radiumhemmet for irradiation of tumours in the pituitary gland. A 3-field technique was used with 2 opposed lateral beams and one beam, with a gantry angle of 30° from the front. The field size was 4×4 cm which requires high precision. When irradiating the front field, the treatment table was rotated 90°. The isocentre was measured and controlled at the simulator and the different treatment units.

As immobilization is desirable to maintain accurate and reproducible treatment position as for brain and head and neck tumours, perspex shells, thermoplastic masks and/or bite blocks are made in our mould room. Normally 2 lateral opposed beams are used at these treatments.

Patients with breast tumours are frequently treated with ^{60}Co gamma radiation in our department. In order to match the 2 tangential breast fields with the 2 parallel opposed AP-beams over the supraclavicular and the axillary regions, a special angled support with a handle for the patient's arm is used.

Treatment of patients for oesophagus carcinoma starts with 2 parallel opposed AP-beams up to 34 Gy in the target volume. This is followed by a 3-field technique (Fig. 2) up to 65 Gy. The patient is always treated in the supine position and no fixation is used.

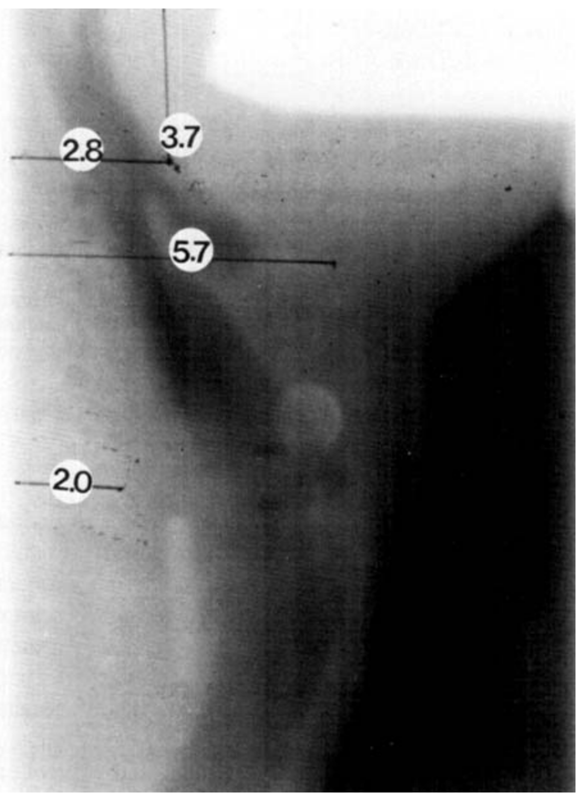

Fig. 1. Typical portal film for a patient in the neck region. Bony landmarks were identified and measurements were made of the distance of each landmark from a field margin as indicated in the figure.

Results

A change of 1 mm in the position of the beam on the Rando phantom could be detected on the portal film. The results of treatment-to-treatment variations in daily studies for various diagnoses are shown in Table 1. The average standard deviation for all sites combined was 3.5 mm. The average discrepancy in alignment between the simu-

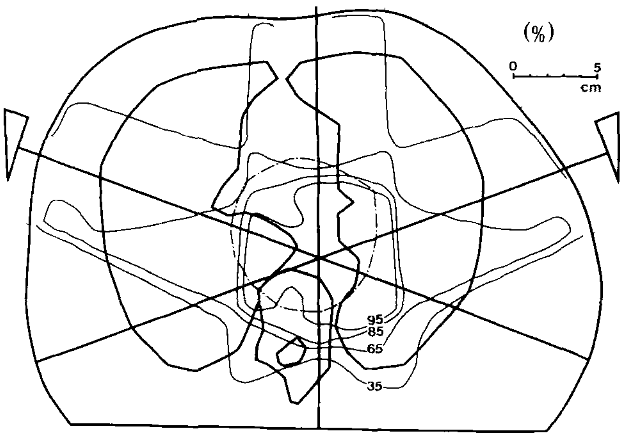

Fig. 2. Treatment of an oesophageal lesion by a 3-beam technique with 8 MV x-rays if a systematic error has occurred in the patient set-up. The border of the target area is indicated by the thick dotted line. The target area is not located within the 95% isodose curve in such treatment.

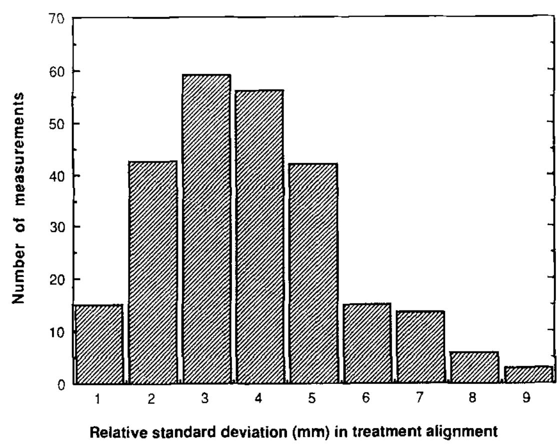

Fig. 3. Frequency distribution of the average standard deviation alignment. Total number of measurements 3082.

lator film and the portal films indicates a good agreement between the alignment of the simulator and those at the different treatment units. Fig. 3 shows the frequency distribution of the average standard deviation for treatment-to-treatment changes.

The maximum discrepancy in alignment between the simulator and the electron accelerators for the frontal beam in treating pituitary adenoma approached 5 mm. The isocentre movement can differ between the various treatment units and the simulator. This causes errors in the patient set-up. A statistically significant difference was detected between the different electron accelerators. The smallest deviation was obtained with the Varian 6/100, which has good mechanical stability and is supported by a very stable treatment table (Rotterman type).

No significant differences in discrepancy was obtained in the ear, nose and throat region when treatments were performed with complex multi-field, custom block arrangements or rectangular beams with or without wedge filters.

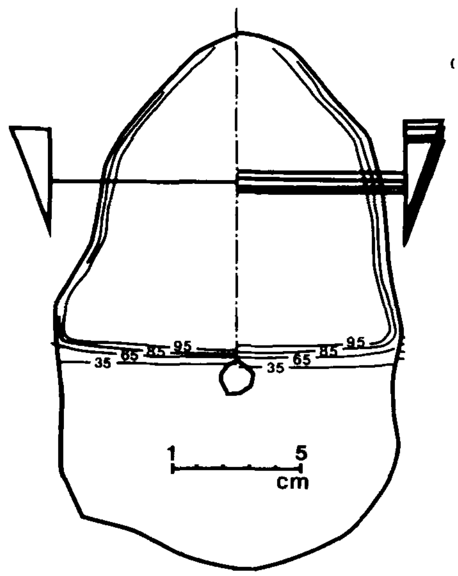

Fig. 4. Treatment of the tongue and the floor of the mouth with 2 lateral parallel opposed wedge 4 MV x-ray beams. The left side shows the prescribed dose plan and the right side the given absorbed dose distribution, assuming a gaussian distribution of the alignment of the beam.

In oesophagus treatment using a three-beam technique, the discrepancy in alignment between the simulator and the accelerator contained a 20 mm systematic deviation for the 2 angle beams. The reason for this was found to be a different patient set-up at the simulator and at the treatment unit. Fig. 2 shows the absorbed dose in the target volume if the treatment had been performed without correction for the systematic deviation in the patient set-up.

Fig. 4 shows the difference between a prescribed dose plan and the given absorbed dose in a patient treated towards the neck with 2 lateral parallel opposed beams with the assumption of a gaussian distribution of the alignment of the field around the prescribed field border.

No significant difference in treatment-to-treatment variations could be detected if the portal film was exposed for a whole treatment session or for a few seconds.

Only 3 serious mistakes and errors were detected on the 642 portal films taken. Thus one treatment was given with a wrong block and one without the prescribed block. One patient was placed in different position on the simulator table and treatment unit table.

Discussion

Radiumhemmet has a long tradition of taking portal films to verify that patients receive the treatment intended. We therefore assume that this study on the variation from treatment to treatment did not influence and/or distort the resultant analysis. Rabinowitz et al. (8) reported that they could not detect any difference in their prospective and retrospective review of patient set-up. In addition, an impressive number of portal films have been taken over a long period.

As simulation of all the beams (with the simulator) for a pituitary adenoma treatment can reach a discrepancy of up to 5 mm, it is sufficient to simulate one of the lateral beams with portal films taken at the accelerator. This procedure causes less errors in the patient set-up, as the isocentre movement differs between various treatment units and the simulator. Normally in this kind of treatment small fields are used, which means that even small alignment errors can easily cause underdosage of parts of the tumour.

The daily variation was relatively large in patients with cancer of the breast and oesophageal cancer. In the treatment towards the supraclavicular and axilla region, lead blocks had to be used. Difficulties in positioning these lead blocks accurately and reproducibly were one of the reasons for the large standard deviations.

Patients with oesophageal cancer are often in bad condition and it is difficult to reproduce the patient set-up with the present technique. Reproducibility of the treatment might in these patients be improved by a fixation system as recommended by Jakobsen et al. (9).

The uncertainties in beam alignment found at Radiumhemmet are consistent with those reported in the literature from other hospitals (8). Although we used laser alignment and a fixed contoured mask for all patients treated towards head and neck and mantle fields, beam alignment error of the order of ±3 mm was obtained.

With present facilities it is difficult to overcome the uncertainties in beam alignment. Dose planning must therefore take these uncertainties into account (Fig. 4) to ensure that the prescribed tumour dose and/or dose in adjacent sensitive organ will be received. It is also important to have an adequate quality programme for the simulator and the treatment units. In addition the mechanical stability of a simulator should be better than the stability of the treatment units in order to fulfil the present need of accuracy and precision in radiation therapy.

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