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Technical note

Accuracy of field alignment in radiotherapy of head and neck cancer utilizing individualized face mask immobilization: a retrospective analysis of clinical practice

Clemens F. Hess*, Rolf-D. Kortmann, Ralf Jany, Andreas Hamberger, Michael Bamberg

Department of Radiotherapy, University of Tübingen, Tübingen, Germany

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Abstract

Deviations between simulation and first check films were quantitatively assessed for 95 unselected head and neck cancer patients. All measured deviations — calculated on the basis of a total of 190 simulation and 380 verification films — were normally distributed, with mean values of 0–3 mm and standard deviations of 3–5 mm. Of the absolute deviations, 50% and 95% were within 3 mm and 9 mm, respectively. These results should be considered in clinical practice when prescribing safety margins and adequate cut off doses for sparing critical organs in head and neck cancer.

Keywords: Radiotherapy; Head and neck cancer; Accuracy; Reproducibility

1. Introduction

In head and neck tumours, radiotherapy seeks maximization of the probability of local tumour control and minimization of the risk of significant complications. The safety margins included in the planning target volume must be carefully chosen to reflect uncertainty in the assessment of microscopic extension of disease and the expected accuracy of field alignment during treatment planning and treatment delivery [6–8,10,11,16, 17,20,21].

From the available literature, however, it remains difficult to draw reliable conclusions on the accuracy of field alignment in routine head and neck radiotherapy. In most reports, the number of patients is limited, or the patients included have undergone a prospective protocol associated with an increased care of the hospital staff [1,3,4,9,16,18,19]. In the study presented here we retrospectively assessed the discrepancies of field alignment between simulation and first check film for 95 unselected head and neck tumour patients treated with contemporary radiation techniques. For these patients, the position of anatomic landmarks within the treatment field were compared with the position of the same landmarks within the field defined with a diagnostic quality film taken on a treatment simulator. The distribution of the deviations were quantitatively analysed, and the possible impact of these deviations on the appropriate prescription of safety margins in clinical routine is discussed.

2. Material and methods

2.1. Patients and treatment technique

Ninety-five consecutive patients with head and neck tumours were included in the study. All patients were immobilized with individual synthetic cast material (orfit, Fa. HEK, Lübeck, Germany). The primary tumour and the adjacent lymph nodes were treated with isocentric lateral opposed fields up to a total dose of 36 Gy, with a 6 MV linear accelerator. Thereafter, the isocentic lateral opposed fields were reduced to spare the spinal cord, with the dorsal edge of the fields in the mid-

* Corresponding author, Zentrum Radiologie, Abteilung für Strahlentherapie, Robert-Koch-Str. 40, D-37075 Göttingen, Germany.

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dle of the vertebral bodies. The dorsal neck was boosted by 8–10 MeV electrons. Individualized mouth blocks fixed to a tray were used to spare as much mucosa as possible. When needed, the lower cervical and supraclavicular nodes were irradiated with an anterior field at a SSD of 100 cm. Total doses were 70 Gy to the untreated primary tumour and macroscopically involved lymph nodes and 50 Gy to the regions of suspected subclinical disease. All fields were delivered each day, with daily sessions of 2 Gy, 5 sessions a week.

2.2. Simulation and check films

Simulation films of both the initial and the reduced lateral opposed portals were taken before start of treatment. They were taken from the right side only. Check films (Cronex DOT 1, du Pont) were taken from either side during the same session and were exposed during the duration of one field. These films were taken during the first session of the initial radiation fields (1–3 days after initial simulation) and of the reduced fields (approximately 4 weeks after simulation).

2.3. Measurements

For each lateral portal two anatomical landmarks — the tip of the epiglottis, and specifically defined landmarks at the ventral border of an individually selected vertebral body — were identified on the verification films. The same landmarks were then identified on the simulator film. The positions of these landmarks were measured with respect to the ventral (anteroposterior measurements) and to the upper margins (craniocaudal measurements) of the lateral fields. Consequently, two anteroposterior and two craniocaudal measurements were performed for $2 \times 95 = 190$ simulation and $4 \times 95 = 380$ verification films.

For each particular simulation and verification film the measurements were demagnified to a standard distance (isocenter).

2.4. Data analysis

For each measurement on each portal film the difference between the demagnified portal and the corresponding simulator film measurements was determined. These differences were determined between the simulation and the check films for the initial fields and the reduced fields, respectively defining field deviations between simulation and first treatment set-up (comparison I). In addition, anteroposterior and craniocaudal deviations were determined between right-sided and left-sided verification films of the same session (comparison II) and between corresponding verification films of the initial and the reduced field (comparison III). All deviations were calculated with respect to either anatomic landmark.

Student's t-test and the F-test were used for statistical analysis. For each particular comparison (I–III), histograms of the deviations were determined. In addition, cumulative frequency distributions of the absolute deviations were calculated (Fig. 1). The ordinate of this plot gives the percentage of cases in which the error is less than or equal to the value given by the abcissa.

3. Results

Three different comparisons (I–III) were performed for four particular measurement (anteroposterior and craniocaudal measurements with respect to two dif-

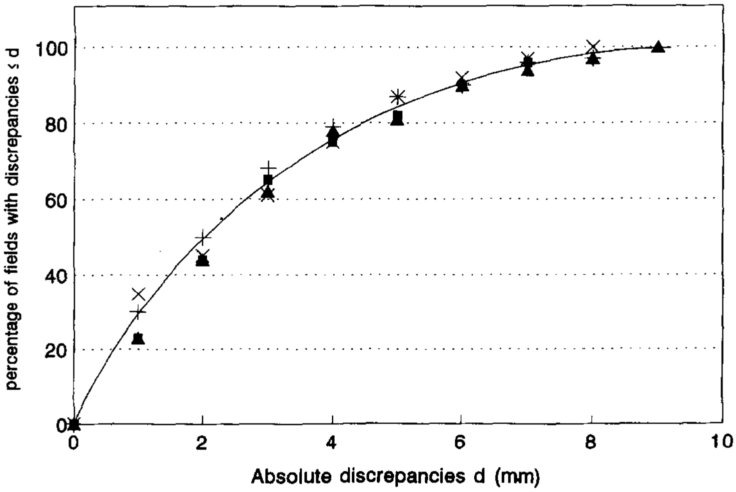

Fig. 1. Absolute discrepancies between corresponding measurements taken from right sided simulation and first check films, as measured with respect to bone structures. Cumulative frequencies of the absolute discrepancies are shown for anteroposterior (■, initial fields; ▲, reduced fields) and craniocaudal deviations (+, initial fields; ×, reduced fields).

ferent landmarks). Corresponding anteroposterior and craniocaudal deviations measured with respect to the epiglottis and with respect to bony structures revealed significant correlations, with correlation coefficients between 0.59 and 0.83. Consequently, the selection of a particular landmark did not significantly influence the measured deviations.

For all comparisons (I–III) no significant differences could be detected between the anteroposterior and craniocaudal deviations (Fig. 1).

3.1. Comparison I: Deviations between simulation and verification films (initial and reduced portals)

Discrepancies between simulation and first treatment set-up were determined for 2 × 95 = 180 simulation and 2 × 95 = 180 right sided verification films. For each particular measurement, the deviations between the simulation and the first check were normally distributed, with mean values between 0.1 mm and 2.8 mm, and with standard deviations between 3.0 mm and 4.6 mm. The cumulative frequency distributions revealed that 50% and 95% of the absolute differences were less than 1.8–2.9 mm and 6.3–9.0 mm, respectively. The deviations were similar for the initial fields as for the reduced portals (Fig. 1).

3.2. Comparison II: Deviations between right sided and left sided verification films of the same session (initial and reduced portals)

Differences of corresponding measurements were determined between the right sided and left sided portals taken during the same session. These deviations (determined for a total of 2 × 95 sessions) were equally normally distributed, with mean values between −0.5 mm and +0.6 mm and standard deviations between 1.8 mm and 2.3 mm. Again, the deviations were similar for the initial and the reduced radiation fields, with 50% and 95% of the absolute deviations being less than 0.9–1.3 mm and 4.1–5.3 mm, respectively.

3.3. Comparison III: Deviations between verification films of the initial and the reduced fields

Comparisons of corresponding measurements between the initial and the reduced portals revealed mean deviations between −1.8 mm and 1.4 mm, with standard deviations between 2.9 and 6.1 mm. These standard deviations, however, were not significantly greater than the standard deviations for the comparison between the simulation and first check films. Of the absolute deviations, 50% and 95% were less than 1.7–2.9 mm and 9.4–12.0 mm, respectively.

4. Discussion

In our study discrepancies between simulation and first check films were quantitatively assessed for 95 unselected head and neck cancer patients treated with contemporary radiation techniques, with the patient's head immobilized by individualized face masks. The linear deviations were normally distributed with mean values of 0–3 mm and standard deviations of 3–5 mm. Of the absolute deviations, 50% and 95% were within 3 mm and 9 mm, respectively, and about 20% of the absolute deviations exceeded 5 mm. These figures representing the accuracy of field alignment in clinical routine are similar to those recently reported for limited numbers of prospectively analysed head and neck cancer patients [12,16,18]. We could not find, however, any significant differences between the discrepancies in anteroposterior and craniocaudal direction.

Recently it has been suggested that most of the systematic errors which affect the overall quality of the treatment can be detected with the first check, since field placement errors have been shown to be considerably more prominent between simulation and the first check film than during the subsequent course of treatment delivery [5,16,18]. Therefore, our data may be predictive for the expected accuracy of field alignment in clinical practice. In head and neck cancer, this may be particularly important for the prescription of adequate safety margins (e.g., with respect to the spinal cord), and of appropriate 'cut off doses' for the reduction of lateral opposed fields. Others, however, have argued that setup errors cannot be estimated on the basis of the first check alone [14].

In our series of cases, corresponding measurements on the verification films of the initial and the reduced portal have also been compared. As these deviations were similar to those between simulation and first check films, our results indicate that the transfer from the simulator to the treatment machine did not significantly contribute to the measured discrepancies in our retrospective study [19]. Therefore, random inaccuracies may be more important in clinical routine than in the treatment of selected patients which may be due to an increased care of the technicians and physicians within prospective protocols [14,16].

It is not possible, however, to draw reliable conclusions from our study on the contribution of systematic and random errors, because a series of repeated verification films during the course of treatment has not been performed [2,3,14–16]. However, methodological difficulties have to be considered when assessing the reproducibility of field alignment with repeated verification films in clinical practice. Primarily, discrepancies between simulation and verification films which are clearly beyond clinical tolerance values, have to be corrected for ethical reasons (e.g. accidental errors). Therefore, a series of verification films can only be analysed for patients with tolerable discrepancies. Second, even with the possibility of daily acquisition of electronic portal images, it is extremely difficult in clinical routine to confidently define quantitative levels for a corrective action [1].

In our study, discrepancies between the simulation and verification films were similar for the initial portal and the reduced lateral opposed fields. Since the verification films of the reduced portal were taken approximately 4 weeks after simulation, an increased mobility of the head and neck or significant changes in patients position or anatomy during this time period could not be detected. In addition, comparisons between the right sided and left sided verification films revealed no additional error induced by mechanical inaccuracy or patient motion during the same session.

Potential errors should be considered when confidently identifying anatomic landmarks on simulation and check films in head and neck radiotherapy [15,19]. In our series of cases, however, no significant influence of particular landmarks on the measured deviations could be detected. Significant correlations could be found between corresponding measurements taken with respect to different anatomical landmarks describing identical field displacements. These results suggest that the selection of particular landmarks did not significantly affect the deviations found in our study.

In conclusion, our study indicates that 95% of the absolute deviations between simulation and first treatment set up are within 1 cm in radiotherapy of head and neck cancer, if individualized head immobilization and contemporary radiotherapy equipment are employed. Our detailed quantitative analysis including cumulative frequency distributions of field deviations should help to prescribe adequate safety margins and appropriate 'cut-off doses' in clinical practice, not only for opposed field techniques, but also for more complex multifield techniques with less steep dose gradients. Further experiences with electronic portal imaging systems in clinical routine will show whether our data are confirmed with an even greater database on radiation field displacements in clinical practice.

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