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Daily on-line set-up correction in 3D-conformal radiotherapy: is it feasible?

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ABSTRACT

Aims and background. The aim of this report was to investigate the feasibility in terms of treatment time prolongation of an on-line no-action level correction protocol, based on daily electronic portal image verification.

Methods and study design. The occupation of a linear accelerator (LINAC) delivering 3-D conformal treatments was monitored for two weeks (from Monday to Friday, 10 working days). An electronic portal image device I-View (Elekta, UK) was used for setup verification. Single-exposure portal images were acquired daily using the initial 8 monitor units delivered for each treatment field. Translational deviations of isocenter position larger than 5 mm or 7 mm, for radical or palliative treatments, respectively, were immediately corrected. In order to estimate the extra workload involved with the on-line protocol, the time required for isocenter check and table correction was specifically monitored.

Results. Forty-eight patients were treated. In all, 482 fractions had electronic portal images taken. Two hundred and forty-five setup corrections were made (50.8% of all fractions). The occupation of the LINAC lasted 106 h on the whole. Twelve h and 25 min (11.7% of LINAC occupation time) were spent for portal image verification and setup correction. On the average, 4.3 fractions per hour were carried out.

Conclusions. When used by trained therapists, ideally, portal imaging may be carried out before each fraction, requiring approximately 10% of LINAC occupation time.

Key words: electronic portal imaging, quality control, radiotherapy, setup error.

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Introduction

Accuracy in patient positioning during fractionated radiotherapy is of great interest, particularly with novel irradiation techniques, which allow tight conformation of dose distribution. Portal imaging to measure setup errors is a standard practice in a large number of institutions[1]. Electronic portal imaging devices (EPID) are widely used for setup verification. The new portal imaging technology allows for speedy and accurate assessment of images[2]. EPID-guided setup corrections based on a quantitative protocol have been applied successfully for many treatment sites[1,3].

On the basis of one or more measured setup deviations, patient position can be corrected during the same fraction, applying an on-line correction, or at the subsequent fraction, using an off-line correction. In an off-line decision protocol, the setup correction for a given treatment fraction is entirely based on setup measurements in previous fractions. Therefore, such protocols can only reduce the systematic setup errors but not the random day-to-day setup variations[4]. Furthermore, it was observed that if the setup error drifts during the treatment course, a time trend is often present[5-7], so a correction based on images acquired at the initial phase of treatment could be inadequate[1]. Another drawback of off-line correction strategies is that it is impossible to correct setup errors occurring during the delivery of the fraction (intrafraction deviations). Furthermore, a complex procedure is often required to establish the magnitude of correction. Statistical data available for a specific treatment group or for the specific patient to whom the correction rule is applied are often needed[8].

Given these limitations, potential advantages of daily on-line correction protocols appear obvious. One report recommended that frequent portal imaging is needed, with the ideal being daily imaging[9]. However, two main disadvantages of on-line correction protocols have been described: 1) a mean increase in patient setup time[8,10,11], which can be as high as 45-55%[12,13]; 2) an increase of up to 10% in the dose prescribed to surrounding tissues if localization images are made[14]. Despite such theoretical limitations, an on-line no-action level (NAL) correction protocol, based on daily electronic portal image verifications, has been used for 5 years in our radiotherapy unit. In the first period, the protocol was used to verify the reliability of our immobilization devices. Subsequently, we chose to maintain the same protocol because new techniques, requiring high accuracy in patient positioning, were introduced in our radiotherapy unit.

The aim of the study was to investigate the feasibility in terms of treatment time prolongation of an on-line NAL correction protocol based on daily electronic portal image verification. Furthermore, the efficacy in improving setup accuracy, in terms of percentage of setup deviations detected, was estimated.

Material and methods

The occupation of a linear accelerator (LINAC), delivering 3-D conformal treatments, was monitored for two weeks (from Monday to Friday, 10 working days). Radiotherapy was delivered with the LINAC Precise (Elekta Oncology Systems, Crawley, UK). An EPID I-View (Elekta, UK) was used for setup verification. Various stabilization devices were used. For the breast area, a home-made breast board was used. For the thoracic and abdominal area, patients were treated supine and were immobilized using vac-loc bags or a wing board. For the pelvic area, patients were positioned prone on a home-made up-down table[15]. A thermoplastic face mask was used for immobilization of head-and-neck cancer patients. On each treatment day, patients were positioned using laser alignment to reference marks (one anterior and two lateral setup crosses) on their skin and/or on immobilization devices. Single-exposure portal images were acquired daily, by using the initial 8 monitor units delivered to each treatment field. The portal image acquisition began automatically at the time of "beam on". The image quality was improved by adjustment of the display contrast. Digitally reconstructed radiographs processed by the treatment planning system (Plato System, Nucletron, The Netherlands) were used as references. A NAL protocol for setup correction was used as follows. Deviations of isocenter position were systematically measured by comparing the distance between bony landmarks and field edges on both digitally reconstructed radiographs and portal images. Translational deviations of isocenter position larger than 5 mm or 7 mm, for radical or palliative treatment respectively, were immediately corrected. The therapists were instructed to enter into the bunker and verify the correspondence of laser beam with isocenter demarcation on skin and/or on immobilization devices. In case of lack of correspondence, the patient was correctly positioned and the process repeated. Otherwise, the position of the table was adjusted according to deviations previously measured. Portal images were again acquired by administering further 8 monitor units. Corrections were made if needed until the tolerance limit of isocenter position deviation was accomplished. The procedure was repeated for each field of the patient's daily treatment. In case of deviation lower than tolerance level, dose delivery of the corresponding field was completed. In order to estimate the extra workload involved with the on-line protocol, the time required for landmark match and table correction was specifically monitored.

Results

During the sample period, 48 patients were treated (Table 1) and 315 sessions were completed. In 148 sessions, radiotherapy was delivered to one planning target volume (PTV) only. In 167 sessions, two PTV were simultaneously irradiated using a concomitant boost technique. Overall, 482 PTV were irradiated.

A total of 2041 EPI were reviewed. In 785/2041 (38.4%) images, the treatment field size was too small for clinical interpretation. However, it was possible to check the isocenter position at least for one PTV in all patients, and 245 corrections of setup were carried out (12.0% of all fields, 50.8% of all treated PTV).

LINAC occupation lasted 106 h on the whole. Twelve h and 25 min (11.7% of LINAC occupation time) were spent for portal image verification and setup correction. One fraction (considered as treatment of one PTV) lasted a mean time of 13 min and 11 s. Therefore, on the average, 4.3 PTV per hour were irradiated. The mean time slot per patient (time from entry to exit from the bunker) was 19 min and 42 s.

Table 1 - Patient characteristics

	No.	%
Patients	48	100
Sex M/F	19/29	39.6/60.4
Median age, yr (range)	60 (20-86)	
Median body max index (range)	25.62 (18.6-37.9)	
Body area		
Head & neck	8	16.7
Chest	16	33.3
Abdomen	6	12.5
Pelvis	18	37.5
Treatment intent		
Radical	44	91.6
Palliative	4	8.4
Immobilization device		
Breast-board	10	20.8
Up-down table	17	35.4
Thermoplastic face mask	6	12.5
Vac-lock bag	5	10.4
Wing board	8	16.7
None	2	4.2
Sessions[a]	315	
Fractions[b]	482	
LINAC occupation time (h)	106	

[a]Patient accesses to the bunker. [b]PTVs treated (167 patients had two treated PTV per session). LINAC, linear accelerator; PTV, planning target volume.

Discussion

The occupation of a LINAC delivering 3-D conformal radiation therapy was monitored for 10 days. The aim of the study was not to evaluate the setup errors or the reliability of the immobilization devices. In this regard, several studies have been already published[8,16,17]. The purpose of the present study was to evaluate the feasibility of an on-line setup correction strategy based on daily portal imaging in terms of LINAC occupation time. We found that daily portal image verification and on-line setup correction required approximately 10% of LINAC occupation time, with a mean time spent per fraction of 13 min and 11 s. These results are quite satisfactory, as 15 min per fraction is the time required in most radiotherapy units[18].

An analogue on-line correction strategy was used in gynecologic cancer patients by Stroom *et al.*[19] Similarly to our findings, they observed that extra treatment time for an on-line procedure per treatment fraction varied from 1-2 min if no table translation was required and from 3-5 min if a table correction was necessary. Van de Steene *et al.*[20] evaluated the feasibility of daily on-line correction of setup errors using electronic portal imaging in the irradiation of lung tumor. Contrary to our results, they found that the mean extra time fraction was 65%, with more than half coming from the error measures. However, in the latter experience, evaluation of portal images required in any case objective measurements performed by the operator, and an action level of 2 mm was applied. In our experience, an action level of 5 or 7 mm was applied for 3-D conformal treatment with radical or palliative intent, respectively. A deviation of less than 3 mm was otherwise accepted for intensity-modulated and extracranial stereotactic radiotherapy.

A large percentage of fractions (50.8%) required corrections based on daily portal imaging. In our radiotherapy unit, a margin larger than 5 mm is always added to the clinical target volume to define the PTV (10-15 mm for the thoracic and abdominal area, 8 mm for the pelvic area). Therefore, our correction strategy, having an action level of 5 mm or 7 mm, for radical or palliative treatments respectively, appears adequate also considering organ motion. The importance of daily electronic portal imaging in radiotherapy was also pointed out by Bell *et al.*[21] They used EPID during treatment in 20 randomly selected patients. It was found that 80% of the patients needed a treatment center move during the course of their treatment. They also observed that errors occurred throughout the whole treatment and that it was not possible to predict patients who could have daily imaging omitted.

One of major concerns about daily portal imaging is the contribution to total dose given by concomitant exposures to healthy organs and tissues. It was reported that generally this is in the range of 1-10% but can be as high as 20% for bone marrow and bone surfaces[14]. The use of single exposures instead of double exposures together with the use of treatment monitor units eliminates this problem. However, single exposure portal images can be useful for setup verification only in case the area of interest is large enough to provide anatomic references. Particularly, Hatherly *et al.*[22] suggested that field-only EPI can be considered to be at least as clinically useful for treatment verification in the following sites: breast, chest, hip, spine, and large pelvic fields. Otherwise, portal films using a standard, double exposure technique were considered necessary for partial brain fields, small pelvic fields, extremities, and radical head and neck fields.

In our radiotherapy unit, a large part of treatments is delivered as a concomitant boost (i.e., irradiation of whole breast concomitant with the tumor bed), so that portal images of a larger treatment volume are used for isocenter verification of the whole treatment. Therefore, besides the well-known radiobiological rationale[23], compared to the sequential technique, an additional advantage of the concomitant boost technique may be represented by the easier correction of setup errors.

It should be noted that this experience was performed after 5 years of daily on-line portal imaging use. Therefore, the results of our analysis are poorly adaptable in other radiotherapy units with less experience in the intensive use of EPID. In these centers, the time needed for verification and corrections may be more prolonged.

On the other hand, our strategy of on-line correction can be further improved. More efficient EPID (e.g., amorphous silicon) could lead to speeding up of the image verification process. Furthermore, using treatment couches with remote software control, such corrections can be accurately carried out within seconds[24].

From all these considerations, it can be assumed that the percentage of time required for an on-line NAL correction strategy, based on daily electronic portal image verification, depends on a number of factors such as the action level, the method of image verification, the type of EPID, and the availability of treatment couches with remote software control. Therefore, our results cannot be extrapolated to other centers. However, our experience may be at least indicative of the magnitude of the time required for this type of verification.

In conclusion, the increasing complexity of radiation techniques results in an increasing demand for precision in treatment delivery. From a theoretical point of view, on-line portal imaging is the most effective way to verify and correct setup errors. Our results support the hypothesis that daily portal imaging may be a useful tool for patients undergoing 3-D radiotherapy. When used by trained therapists, portal imaging may be performed before each fraction requiring approximately 10% of LINAC occupation time.

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