Verification of the Patient Positioning in the Bellyboard Pelvic Radiotherapy

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ABSTRACT

The size and shape of the treatment fields applied in radiotherapy account for uncertainties in the daily set-up of the patients during the treatment. We investigated the accuracy of daily patient positioning in the bellyboard pelvic radiotherapy in order to find out the magnitude of the patients movement during the treatment. Translational as well as rotational movements of the patients are explored. Film portal imaging is used in order to find patient positioning error during the treatment of the pelvic region. Patients are treated in the prone position using the bellyboard positioning device. Thirty six patients are included in the study; 15 patients were followed during the whole treatment and 21 during the first 5 consecutive treatment days. The image acquisition was completed in 85% and systematic and random positioning errors in 453 images are analyzed. Translation of the patient during the treatment caused set-up errors that ranged up to 30 mm and rotation of the sacrum ranged up to 14@. We found out that most of the patients had time trend (drift of the position or angle during the time). This is predominant in the first few days while patient accommodate to uncomfortable prone position in the bellyboard. Safety margins that will ensure 90% probability of depositing at least 95% of the prescribed dose in the target are calculated according to translational movement of the patient. No action level, off line, set-up protocol is employed to correct patient position because of the translational movement. To correct for the rotation of the patient anatomy, correction of the custom shielding blocks should be employed.

Key words: pelvic radiotherapy, verification, bellyboard

Introduction

The pelvic radiotherapy is often indicated for patients with cervical, uterine and rectum carcinomas. During the radiotherapy, total doses of 40–50 Gy to the whole pelvis can cause early or late complications of the small bowel[1,2]. Useful methods to reduce the irradiated small bowel volume are: making individualized normal tissue blocks and use of the bellyboard, where patients are in the prone position[2,3].

Uncertainties in the daily set-up of the patients during the treatment can give rise to the complications or influence the results of the treatment[2]. The size and the shape of the treatment fields applied in radiotherapy account for uncertainties in the daily set-up of the patients during the treatment. Those uncertainties can be reduced by repositioning of the patient according to the set-up verification[4,5].

We investigated the accuracy of daily patient positioning in the bellyboard pelvic radiotherapy in order to find out the magnitude of the patients movement. Translational as well as rotational movements of the patients are explored. According to this, safety margins and protocol for repositioning of the patients is chosen.

Materials and Methods

Thirty-six patients were included in this study. 15 patients were followed during the whole treatment and 21 patients were followed during the first five consecutive treatments days.

All patients were treated using the three field box technique at the linear accelerator Siemens Mevatron

MD2. Patients are simulated at the conventional simulator SIMVIEW 3000. Shielding was done with conformal Cerrobend blocks individually made for each patient. All patients were simulated in the prone position using our custom-made bellyboard. The isocenter position was visualized using laser equipment and marked on patients' skin by markers. To enable the reproducible position of the patient, the opening of the bellyboard was marked by two lines on the skin.

During the simulation procedure two sets of simulation films were obtained. One film was taken for the anteroposterior field and the other for one of the lateral fields. During the treatment session, for the verification of positioning of the patient, we were using the Kodak EC-L film system. The translational setup errors in patient positioning are defined by the deviations from the measured distance between the centre of the field and visible bony anatomical landmarks[4,5,6] along the craniocaudal (CC), anteroposterior (AP), and lateral (ML) axis. Displacements of the ML and CC direction were measured from the anteroposterior field, and AP direction from the lateral field. The ML displacement was defined as a distance from the isocenter to the pelvic rim; the CC as a distance to the obturator point and the AP as a distance to the symphysis (Figure 1). All deviations in the caudal direction, to the left and dorsum were marked as positive, and the deviations in the cranial direction, to the right and anterior were marked as negative[4].

The rotational setup errors in the patient positioning are defined by the angle deviations of the sacrum. Center of the rotation is defined as point O at the edge of the sacrum and angle a is defined as angle between horizontal line and line between points O and S, where length OS is defined as ¼ of the y field size (Figure 1).

The first 15 patients were followed during the whole treatment and we examined the presence of time trends. The time tren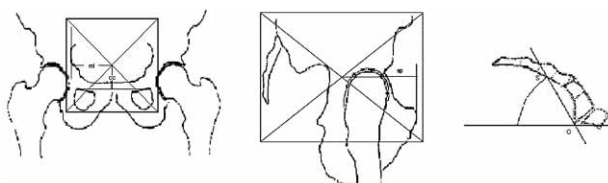d is defined as drift of the field displacement in a one, systematic way during the treatment. If the time trend exists, the correction of the systematic error may not be accurate[7]. Time trends were investigated using a linear regression approach.

The systematic error (SE) is defined as the mean displacement of the treatment isocenter from the planning isocenter[6]. Random error (RE) is defined as a deviation of the each individual position from the mean position of the patient.

The systematic error is the main factor when considering the margin size for setup uncertainties[6–8]. The systematic error for the entire group (SEeg) was defined as the arithmetic mean of all patients' systematic errors. The random deviation of the patients' SE from SEeg was estimated by 1 SD (SDse). The random deviation of all individual RE around the mean patients' RE was also estimated by 1 SD (SDre). Thus, systematic and random setup errors were calculated for the entire group of patients and the safety margin size was formed according to the sizes of those deviations. The margin size is the one that ensures the 90% probability of depositing at least 95% dose in the target[8]. These values are a sensible compromise between the risk of under-dosing the target volume and of excessive overdosing the surrounding healthy tissue[8]. The calculation of the safety margins, H, is done by using the following expression[8].

$$H = 2.5\ SDse + 0.7\ SDre \qquad (1).$$

Because these margins do not include rotational errors, they should be used as the lower limit for safe radiotherapy[8].

We chose to implement strategy called no action level (NAL) protocol[9] for reducing patient setup errors. It means that the position of the patient will be measured during the N treatment fractions, and an unconditional correction of the setup position will be done once at the $(N + 1)$ th fraction. We investigated when to do the correction of systematic positioning error by evaluating setup errors during the whole treatment session.

Results

At the beginning, we checked for the presence of the time trends for all patients' directions. Data were fitted as linear, and the slope of the curve is tested to be less than 4 mm during the whole treatment. For the ML and

Fig. 1. Determination ML, CC, AP and angle displacements.

TABLE 1
THE RANGE OF THE SETUP ERRORS OF 15 PATIENTS INCLUDED IN THE STUDY

	Lateral	Craniocaudal	Anteroposterior
Setup error (mm)	–14.7 to 18	–30.3 to 15.4	–19.2 to 30.5
Systematic error (mm)	–3.1 to 8.9	–11.7 to 2.4	–1.7 to 12.1
Random error (mm)	–9.1 to 16.9	–31.1 to 18.2	–22.1 to 17.6
SDse (mm)	1.9	2.6	2.5
SDre (mm)	2.7	3.3	4.1
SM (mm)	7.0	8.3	9.4

CC directions there was no evidence of the time trends. In the AP direction, a time trend existed in an aged, obese patient with a hip problem. Since that patient was very difficult to position, we excluded his AP data from our analysis.

The ranges of the errors are shown in the Table 1 together with ranges of the systematic and random components of the errors. The systematic and random errors represented by 1 SD are also shown in the Table 1 together with the safety margins (SMs) calculated as explained before.

The calculated SMs are the lower limits for the treatment planning and we will use rounded values in upper directions. Besides, we neglected the existence of the time trends less than 4 mm in all directions, so this value was added to the SM sizes. Finally SMs are 11 mm, 13 mm and 14 mm in ML, CC and AP directions respectively.

To avoid random errors to cause repositioning of the patient, we investigated how many images (fractions) should be averaged to determine whether the error is random or systematic. In a direction, the sum of all patients' REs around SE is zero. We determined the fraction number (N) where the random error averaged over 1th, 2nd...N^{th} fraction is a good approximation of the zero value. For the jth patient the array $n_{i,j}$ was formed by averaging all deviations of preceded fractions for a fraction i. Since REs are equally dispersed around the zero value, all patients' arrays will fast converge to the zero value. A characteristic curve for a patient is shown in Figure 2.

At a fraction i = N, the array value can be approximated as it reached the zero value. It means that one can decide how many fractions (N) should be averaged for a
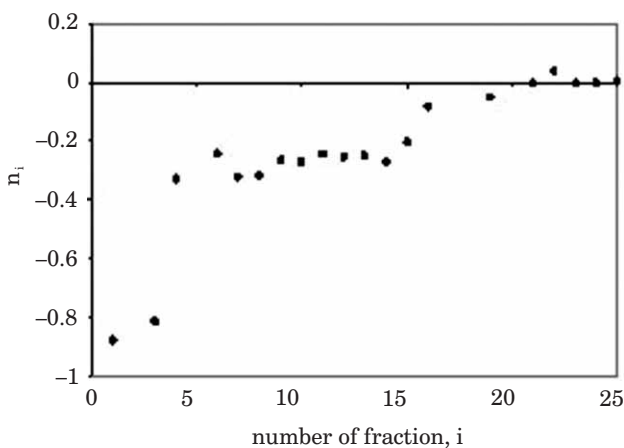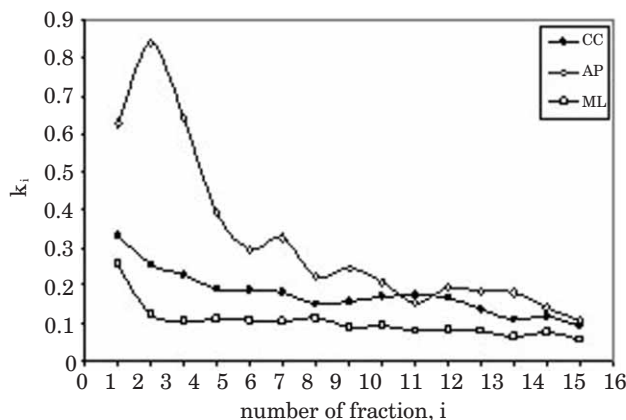

Fig. 3. Averaged random deviations in CC, AP and ML directions for all of the patients during the treatment.

good approximation of the zero value. In this way, for the jth patient, we approximated the systematic error at the end of the treatment (SE_j), with systematic and random error at the chosen fraction. In order to be able to make this decision for a number of patients (M), all absolute values of $n_{i,j}$ are averaged for all of the patients. Thus, we formed the new array $k_i = \frac{1}{M} \sum_j^M |n_{i,j}|$ of average absolute REs at a fraction i for all fractions. Again, the array converges to the zero value and one can decide how many fractions should be averaged for a good approximation of the zero value. In this way a number of fractions, i = N, for a group of patients is found, which can be averaged to represent a good approximation of the systematic error at the end of the treatment. The calculation is done in all of the directions. Arrays of k_i values are shown in Figure 3.

According to the Figure 3, numbers of images that must be taken for a patient were 3 in the ML, 4 in the CC and 5 in the AP direction. Since deviations in ML and CC directions are measured from the same image we decided to average four images in the ML direction as well.

After establishing our NAL protocol, 21 patients were repositioned after the first five consecutive treatments days. Repositioning was the largest in AP direction and ranged up to the 32 mm.

Except translational, also rotational movements of the patient anatomy was observed. Approximately half of the patients had a time trend greater than 6 degrees during the whole treatment. The rest of the patients had accommodated in the first few fractions and then the angle remained at the same value (Figure 4).

Fig. 2. Array of averaged REs around SE in AP direction for a jth patient. After all REs are averaged array ends at zero value.

TABLE 2
THE RANGE OF THE ROTATIONAL ERRORS

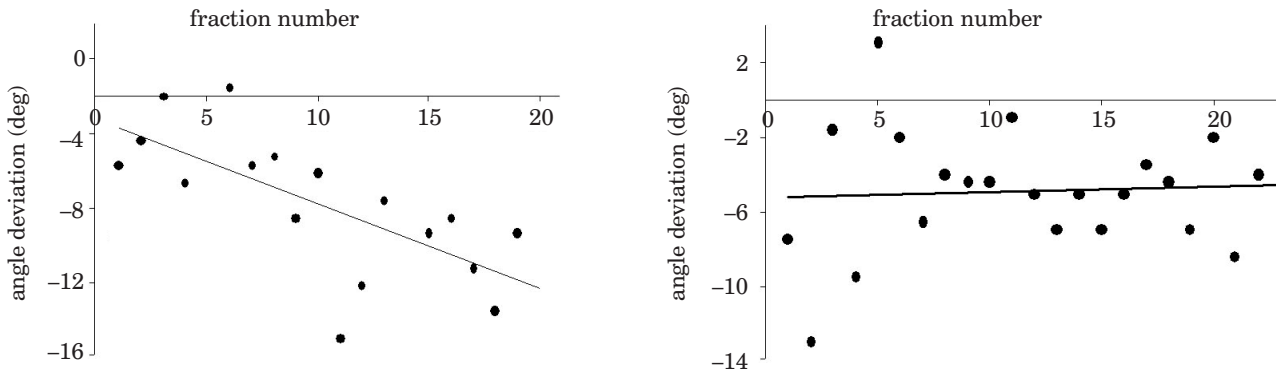|	Setup error range	Systematic error range	SEeg	SD
Angle of the sacrum (°)	–14 to 11.5	–6.3 to 8.4	–1.9	2.7

Fig. 4. Changes of the sacrum angle: the drift during the whole therapy and accommodation in the first few fractions.
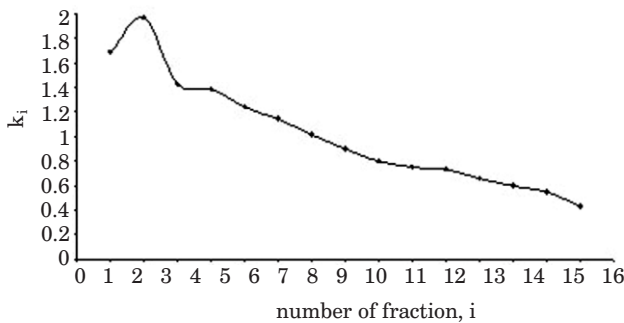

Fig. 5. Averaged random angle deviations for all of the patients during the treatment.

The range of the systematic errors represented by 1 SD is shown in the Table 2.

The angle defined at Figure 1 showed deviations in range of –14 to 11.5 degrees. It corresponds to the drift of approximate ±1.5 cm from the custom block in point S defined at the Figure 1. It can be corrected by changing the shape of the shielding blocks.

We also calculated averaged random deviations of the rotation for all of the patients during the treatment. Since time trends exist in a half of the patients systematic error can not be corrected. So, one can not decide how many fractions should be averaged for a good approximation of the zero value (Figure 5), thus off-line protocol can not be used.

Discussion and Conclusion

Out of systematic and random setup errors the safety margins were calculated. They were 11 mm in the ML, 13 mm in the CC and 14 mm in the AP direction. To find out how many images must be taken to decide that the setup error is systematic, the average REs of all patients during the treatment were compared. It is possible to decide when this error is close enough to zero for a group of the patients, so at that fraction, the error can be considered systematic (Figure 3). Numbers of images that must be taken are 4 in ML and CC directions and 5 in the AP direction. The group of the patients included in the study is assumed to be representative for treatments done at our department.

Only one patient showed time trend in one direction to be greater than 4 mm through the treatment and those data were excluded from the study. That patient was elderly, obese and had a hip problem. We decided that the patients difficult to position by bellyboard would be planed in the supine position.

Rotational movements of patients' anatomy have been observed. It should be corrected by correcting the shape of the normal tissue blocks. Since we do not have MLC it is extremely hard to correct for this and this is omitted at this time. Using electronic portal imaging devices (EPID) and multi leaf collimator (MLC) it is possible to correct on a daily basis.

Systematic and random translational errors reported are comparable to the results published in the referenced studies of gynecological patients[2,10]. The safety margins extracted from this study are smaller than the margins employed before at the department and they are on the upper side of the range of other reported results[10]. It is important to note that the most of the published results are from advanced institutions and may not indicate variations applicable to an average, busy department.

Translational and rotational errors can be explained by the specific prone position in the bellyboard device. The position is uncomfortable and patients accommodate in the first few days of the therapy. According to this, it is important to prepare the patient for the uncomfortable position prior the start of the treatment planning.

REFERENCES

1. GHOSH K, PADILLA LA, MURRAY KP, DOWNS LS, CARSON LF, DUSENBERY KE, Gynecol Oncol, 83 (2001) 271. — 2. OLOFSEN VAN ACHT M, VAN DEN BERG H, QUINT S, DE BOER H, SEVEN M, VAN SOMSEN DE KOSTE J, CREUTZBERG C, VISSER A, Radiother Oncol, 59 (2001) 87. — 3. HOLLENHORST H, SCHAFFER M, ROMANO M, REINER M, SIEFERT A, SCHAFFER P, QUANZ A, DÜHMKE E, Med Dosim, 29 (2004) 173. — 4. KASABASIC M, FAJ D, BELAJ N, FAJ Z, TOMAS I, Radiol Oncol, 41 (2007) 48. — 5. CAZZANIGA LF, FRIGERIO M, Radiol Med, 94 (1997) 664. — 6. KRAGELJ B, Radiol Oncol, 39 (2005) 211. — 7. LUDBROOK JS, GREER PB, BLOOD P, D'YACHKOVA Y, COLDMAN A, BECKHAM WA, RUNKEL J, OLIVOTTO IA, Med Dosim, 30 (2005) 76. — 8. VAN HERK M, REMEIJER P, RASCH C, LEBESQUE JV, Int J Radiat Oncol Biol Phys, 43 (2000) 1121. — 9. BORTFELD T, VAN HERK M, JIANG SB, Phys Med Biol, 47 (2000) 297. — 10. HASLAM JJ, LUJAN AE, MUNDT AJ, BONTA DV, ROESKE JC, Med Dosim, 30 (2005) 36.

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KONTROLA POLOŽAJA PACIJENATA U BELLYBOARDU U RADIOTERAPIJI ZDJELICE

SAŽETAK

Veličina i oblik terapijskog polja u radioterapiji pokrivaju nesigurnosti vezane uz dnevno namještanje bolesnika tijekom terapije. Istražili smo točnost dnevnog namještanja bolesnika u *bellyboard*-u prilikom zračenja zdjelice kako bi odredili maksimalnu vrijednost pomaka tijekom terapije. Osim translacijskih, istražili smo i rotacijske pomake bolesnika. U tu smo svrhu koristili filmove za lokalizaciju. Bolesnici tijekom terapije leže na trbuhu u *bellyboard*-u. U studiju je bilo uključeno trideset i šest bolesnika, od kojih smo 15 pratili za vrijeme trajanja cijele terapije, a 21 tijekom prvih pet frakcija. U 85% slučajeva slike su uspjele te smo analizirali sustavne i slučajne pogreške na 453 slike. Pogreške uzrokovane translacijskim pomacima bolesnika tijekom terapije iznosile su do 30 mm, dok je kut rotacije sacruma iznosio do 14°. Većina bolesnika se pomicala tijekom terapije u prvih nekoliko dana dok se bolesnici navikavaju na neudoban položaj u *bellyboard*-u. Rotacija sacruma je uočena kod više od polovice bolesnika tijekom cijele terapije. Uzevši u obzir translacijske pomake bolesnika izračunali smo sigurnosne rubove koji će osigurati 90 postotnu vjerojatnost da terapijski volumen dobije 95% propisane doze. Kako bi ispravili pogreške uzrokovane translacijskim gibanjem pacijenata, uveli smo »*off-line*« protokol za ponovno namještanje bolesnika bez obzira na veličinu pogreške. Za ispravak pogrešaka uzrokovanih rotacijom bolesnika, bilo bi potrebno korigirati zaštitne blokove.