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ORIGINAL ARTICLE

Evaluation of the Treatment Field Deviations in Different Set-up Positions During Thoracic Radiotherapy in Lung Cancer Patients

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OBJECTIVE

The purpose of the study was to evaluate the treatment field deviations in lung cancer patients treated with thoracic radiotherapy (RT) performed using different immobilization devices into three different set-up positions and the influencing factors.

METHODS

Thirty lung cancer patients having palliative thoracic RT indication were randomized into three different set-up positions using different immobilization devices (Group I: arm along the body, Group II: lung board, and Group III: arm supported board). The treatment field center deviation was measured on sternal (X and Y axis) and axillary (z and θ axis) cross. In addition, parameters such as age, pain, pulmonary function test, set-up time, the temperature difference between the treatment room and the outside environment, and patient education level that may cause set-up were evaluated.

RESULTS

Mean intra-fraction field center deviations of 5.66±4.15 mm were observed in the right (z) axis (p=0.049) and 5.53±4.81 mm in the left (z) axis (p=0.015) in Group II which were statistically significantly larger than the deviations in other groups. A statistically significant correlation was found between the indoor and outdoor temperature difference and set-up time.

CONCLUSION

Both set-up positions of Groups I and III, gave better results than the position of Group II. According to our results, if a lung board will be used, adding the arm supporting accessory will be necessary. Random errors can be minimized and the set-up quality improved by using appropriate immobilization devices, minimizing the total set-up time and balancing the in and outdoor temperature by air conditioning system.

Keywords: Immobilization device; inter-fractional motion; intra-fraction motion; lung cancer; set-up error; thoracic radiotherapy.

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INTRODUCTION

Approximately 61% of patients with lung cancer receive radiotherapy (RT) at least once during their cancer treatment period.[1] RT can be applied to the thorax with definitive, neoadjuvant, adjuvant, or palliative aims.

Thoracic RT is an important treatment modality that is frequently used to palliate many symptoms such as hemoptysis, cough, dyspnea, and pain, with a clinical response rate of 50-80%.[2,3] Treatment success depends on various factors. Set-up errors and tumor movements are among the most important parameters influencing the local control and toxicity of thoracic RT.[4]

Minimizing set-up errors is the first step of the treatment planning. Finding an ideal, simple position with appropriate immobilization devices that is easily reproducible daily as well as providing the best immobilization without adversely affecting the dose distribution is one of the factors that will increase the quality of the treatment.

Today, many different expensive accessories are used for immobilization in thoracic RT such as wing boards, vacuum beds, lung boards. The choice of these accessories depends on the needs of the patient, the RT planning technique, the technical facilities of the clinic, and of course, the cost of the equipment to be used. It is known that in developing and less developed countries obtaining expensive accessories are very difficult and sometimes impossible. A consequence, some simple and inexpensive accessories have to be used.

In this study, it was aimed to compare the treatment field deviation values of patients diagnosed with lung cancer who underwent palliative thoracic RT with AP/PA fields, with different set-up positions and immobilization devices if necessary such as arms along the body, lung board, arm supported lung board, and to evaluate the factors influencing these treatment field deviations.

MATERIALS AND METHODS

This prospective randomized study was carried out between April 1 and July 30, 2011, after obtaining the local ethical committee's approval.

Patients

The inclusion criteria were: Histopathologically obtained lung cancer diagnosis, Karnofsky performance scale score (KPS) ≥50, no severe dyspnea and pain, literate ≥18 years old. All patients were treated with two AP/PA fields for palliative intent.

Simulation

The treatment position to be applied to the patients was determined using the Random Numbers Table. The patients were randomized to three arm positions through this method by Sinmed® RT accessories.

- Group I: Arms along the body in supine, neutral position (Fig. 1)
- Group II: Arms fixed over the head on lung board (Fig. 2)
- Group III: Arms over the head on the lung board and using bilateral arm supports board (Fig. 3).

All patients were simulated in the supine position according to the randomization arm, and tomography was taken with a 5 mm slab thickness.

Technique and Dose of RT

Three-dimensional conformal RT was planned on Oncentra Master Planning System® using Siemens® Emotion Computed Tomography with anteroposterior same isocenter fields with 18 MVX photon energy. The patients were treated with median 10 (2-20) fractions.

Patient Set-ups

The information about the identity data, pathological diagnosis, stage, pain scores (between 0 and 10), and pulmonary function test (PFT) of the patients were obtained before the treatment. On the treatment days, before the patient entered the set-up, the outside air temperature in the shadow and the treatment room temperature were measured by the responsible physicist using a digital thermometer to look for the influence of temperature changes on field deviation.

After the set-up disposition, time was measured with a chronometer. Electronic portal imaging (EPI) was prepared, the treatment room was left, and the treatment was begun. The chronometer continued to work during the EPI control.

When the duration of the anterior field was completed, the researcher entered the treatment room, went by the patient and stated that s/he should still not move; the time of the anterior field was recorded from the chronometer and the field deviation measurements were measured on the six axes. After completion of the measurement process, as in daily practice, without any correction in the patient's position, the chronometer was reset for the posterior treatment field, and the same operations were repeated.

Measurement of Field Deviations

For measurement of the field deviations, three crosses including two lateral (axillary line) and one anterior

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Fig. 1. Arms along the body (neutral position).

Fig. 2. Lung board.

Fig. 3. Arm supported lung board.

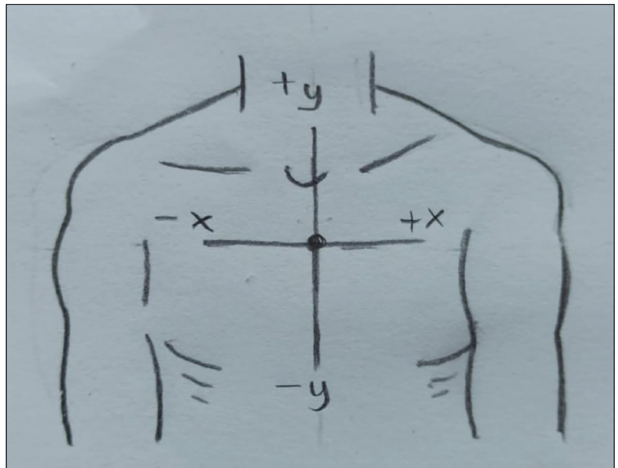

Fig. 4. A/P view of the (x), (y) axis.

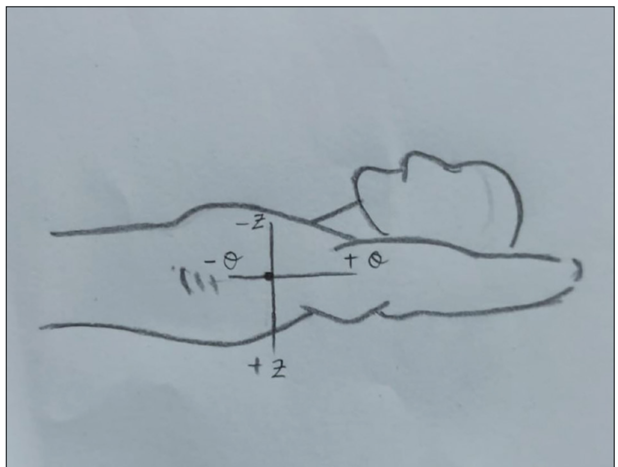

Fig. 5. Lateral view of the (θ), (z) axis.

(on the sternum) were tattooed on the trunk (Figs. 4, 5). The (+) and (-) deviations according to the coordinate axis on the sternum (x: Mediolateral deviation), (y: Craniocaudal deviation), and on the axillary line (z: Anteroposterior deviation), (θ: Craniocaudal deviation) were measured in mm using a ruler.

These measurements were made in every fraction for total two-fraction treatments, in 1st, 3rd, and 5th fractions for total of 5-fraction treatments, in 1st, 3rd, 5th, and 10th fractions for total of 10-fraction treatments and in 1st, 5th, 10th, and 20th fractions in total of 20-fraction treatments.

Calculation of Intra-fractional Field Center Deviation

At the end of the treatment of the anterior and posterior fields, the field deviations according to the center of the laser crosses were recorded.

The study aimed to determine intra-fractional field deviation. The deviation of the center point of the laser cross on the patient with respect to the central axis of the treatment field was recorded. The absolute amount of movement of the patients, regardless of their direction, was calculated. This movement is mentioned in the text as the patient's "field center deviation value" (FCDV).

These measurements have been explained with three examples in Figs. 6-8.

First example: In Fig. 6, the total deviation of a patient whose laser was at (+5) point at the end of the treatment of the anterior field and at (+7) point at the end of the treatment of the posterior field was recorded as total 7 mm deviation in (x) axis.

Second example: In Fig. 7, the total deviation of a patient whose laser was at (-5) point at the end of the treatment of the anterior field and at (-7) point at the end of the treatment of the posterior field was estimated as a total 7 mm in the (x) axis.

Third example: In Fig. 8, patient who was at (+5) point in (x) axis at the end of the treatment of the anterior field then in (-7) point at the end of the treatment of the posterior field, it was recorded as total 17 mm in total by regarding that s/he moved 5 mm at the (+) direction first and moved back 5 mm to reach 0 point, and 7 mm at the (-) direction thereafter from the 0 to the (-7) point.

Taking the "average" of these measured values for each fraction, the "mean total deviation" of each patient was calculated for each axis and these "mean deviation values" (MDV) were used for the statistical analysis.

Statistical Analysis

Non-parametric tests were used for statistical analyzes. First, we evaluated the MDV of each axis for each group, and then inter-fractional differences were evaluated for each measurement.

In the comparison of the field deviation values, the deviation values among the groups in each axis were evaluated using the "Bonferroni corrected Kruskal-Wallis Test" and the in-group inter-fractional measured field deviations for each axis were evaluated using the "Non-parametric Friedman Test."

Parameters such as the pain score, PFT, age, educational status, indoor out-door temperature difference, and the set-up times that can affect the field deviation values were evaluated with the correlation test.

Statistical significance was accepted if p<0.05. The SPSS 15 version was used in the study.

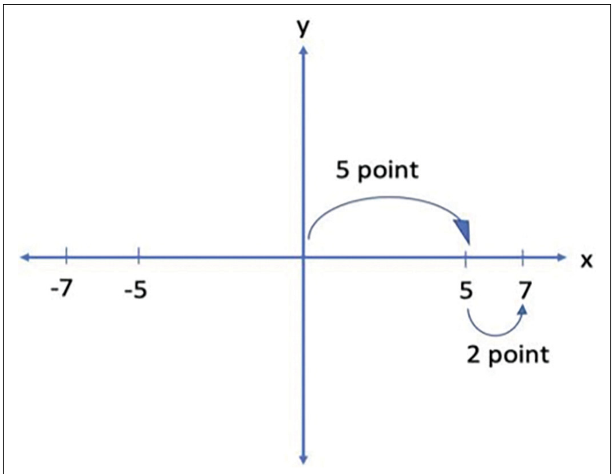

Fig. 6. First example.

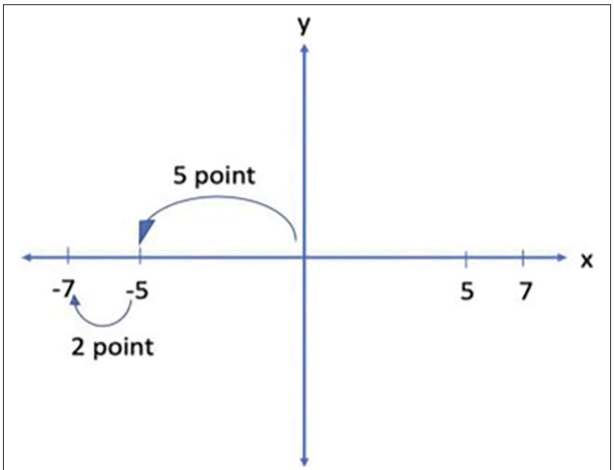

Fig. 7. Second example.

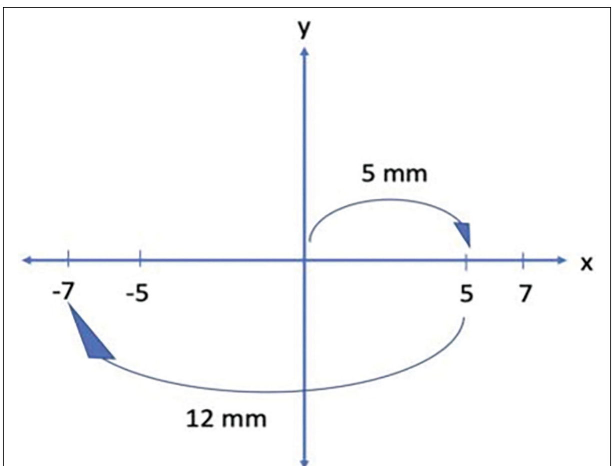

Fig. 8. Third example.

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Table 1 Patient and disease characteristics

	Grup I (Arm along the body)	Grup II (Lung board)	Grup III (Arm supported lung board)
Age (mean (range))	62 (49-76)	59 (47-74)	59 (50-90)
Gender, n			
Female	2	1	3
Male	8	9	7
KPS (mean (range))	70 (50-70)	70 (60-80)	70 (50-90)
Pathology, n			
Small cell carcinoma	3	4	2
Non-Small cell carcinoma	7	6	8
Stage, n			
Extensive stage	2	4	2
Locally advanced stage	1	2	1
Stage IV	7	4	7
Pain score (mean (range))	3 (0-7)	3 (0-7)	3 (0-7)
Metastasis sites, n			
Bone	4	3	4
Brain	2	2	1
Solid organ	5	4	8
Others	7	5	5

KPS: Karnofsky performance scale score

RESULTS

The data regarding age, gender, KPS, histology, stage, mean pain scores, and metastasis sites are presented in Table 1.

Statistical Results of the Measurements

Assessment of Mean Intra-fractional Field Deviation Values of the Axes

The field deviation values of the axes of all three groups are displayed in Table 2. The difference in the mean field deviation amount among all three groups in the (z) axes is statistically significant (right z-axis: p=0.049, left-z axis p=0.015). The highest deviation value was found to be 15 and 13.5 mm in the right and left (z) axes of Group II patients who were treated with the lung board, respectively.

Assessment of Inter-fractional Field Deviation Values Measured for Each Axis

The inter-fractional MDV and the maximum deviation values in each axis within each group are demonstrated in Table 3.

Different types of in-group field center deviations were observed in different axes among fractions, although statistically significant difference was determined in none of the axes. Although not statistically significant, it was noticed that the inter-fractional field center deviations in the z axis were observed to be lowest in Group III patients. It was the highest in Group II patients. In Group II, the deviation values gradually decreased and the decrease was 2.5 times between fractions (from 8.1 mm in first measurement to 3.25 mm in last measurement).

In Group III the least field center deviation difference was observed for Z axis. In the other groups, the FCDV s were varying.

Correlation Test Data Regarding the Parameters Affecting the FCDVs

A statistically significant correlation was found between FCDV and the indoor and outdoor temperature difference and between FCDV and the set-up time of the patients (Table 4). No correlation was found between FCDV and the pain scores and between FCDV and education status. Most of the data about age and PFT showed a statistically significant correlation with FCDV but without any clinical importance due to inconsistent results.

DISCUSSION

The reproducibility of the planned treatment is essential for RT. Today, the patient's immobility is mandatory for the correct irradiation of millimetric sub-segment fields used for stereotactic irradiation, intensity-modu-

Table 2 Assessment of mean intra-fractional field center deviation values of the axes

Groups	R (z)	R (θ)	(x)	(y)	L (z)	L (θ)
Group I						
Mean	3.06	2.12	1.03	0.41	1.43	2.13
SD	2.65	2.51	1.10	0.54	1.46	3.05
Min	0	0	0	0	0	0
Max	7.75	7.00	3.00	1.67	4.00	10.00
Median	1.70	1.37	0.95	0.25	1.50	1.00
Group II						
Mean	5.66	1.95	2.33	0.84	5.53	1.63
SD	4.15	1.80	1.95	0.98	4.81	2.48
Min	0	0	0	0	0	0
Max	15.00*	5.00	5.50	3.50	13.50*	8.50
Median	5.00	1.50	1.58	0.50	3.54	0.83
Group III						
Mean	2.26	1.79	1.16	1.22	1.92	1.33
SD	1.63	1.61	1.02	1.71	1.46	1.57
Min	0	0	0	0	0	0
Max	5.50	4.25	3.00	5.50	4.67	4.25
Median	1.62	1.33	0.87	0.75	1.54	1.12
p-value	**0.049**	0.924	0.292	0.412	**0.015**	0.906

*: Data with the highest deviation value. R: Right; L: Left; SD: Standard deviation

lated RT, etc. Otherwise, set-up errors in the treatment field or geographic missing of the tumor increases the risk of recurrence by leading to insufficient dosing at the borders of the treatment field.[5,6]

In the literature, different systems including the lung board, T-bar, vacuum bed, chest mask, thermoplastic mask covering the arms and the face, and vacuum pillow are seen to be used for patient immobilization during thoracic RT.[7-10] In addition, techniques such as deep inspiration breath-hold and abdominal compression have been attempted for patient stabilization together with the developing technology to decrease the tumor movement and internal margin.[11,12]

Bentel et al.[13] randomized 60 patients receiving radical RT for lung cancer into two arms those in whom immobilization had been applied with the alpha cradle group and those who did not undergo immobilization. The isocenter shift was measured with port films. The deviation was determined in the isocenter in 8% of the patients in whom immobilization had been applied with the alpha cradle and in 14% of the patients in whom immobilization had not been applied (p=0.139). Most isocenter shift reduction was observed on oblique fields (p=0.038).

In a study attempting patient stabilization with the thermoplastic chest mask, a reduction of 3-4 cm was detected in chest wall movements.[7]

In the study of Halperin et al.,[8] T-bar and expanded foam immobilization devices were compared in patients who had undergone thoracic RT. No difference was found between the two methods about concerning set-up errors. For the T-bar immobilization device, standard deviations of the setup reproducibility were 5.1, 3.7, and 5.1 mm in the anterior-posterior, lateral, and longitudinal dimensions, respectively. For the expanded foam immobilization device, corresponding standard deviations of setup reproducibility were 3.6 mm, 5.3 mm, and 5.4 mm, respectively. The authors reported that they preferred the T-bar due to its ease of use.

In another study, an air-injected blanket, which covered the patient and could be fixed onto the table and reduce the breathing amplitude was tried for immobilization of the patients undergoing lung and abdomen radiation. With this system that aimed to reduce the respiration depth, the anteroposterior diaphragm movements decreased to 0.7 cm from 2.6 cm and the craniocaudal diaphragm movements decreased to 1.3 cm from 2.7 cm.[14]

In the study of Giraud et al.,[9] the set-up uncertainties of 21 patients who had undergone 3D conformal thoracic RT with the personalized armrest device similar to alpha cradle were examined. The EPI images of the patients in different fractions were superimposed

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Table 3 Analysis of inter-fractional field center deviation values measured for each axis

Measurement on the axis mean/max (mm)	Group I	Group II	Group III
R (z)			
1st measurement	3.0/16	8.1/19	2.0/7
2nd measurement	4.0/13	5.0/25	2.2/9
3rd measurement	3.9/10	5.4/12	2.7/3.5
4th measurement	0.71/5	3.28/10	2.25/5
p-values	0.352	0.151	0.672
R (θ)			
1st measurement	1.1/10	2.1/8	1.2/6
2nd measurement	3.0/15	2.3/10	2.8/14
3rd measurement	2.9/14	1.4/5	1.6/6
4th measurement	1.14/6	2.57/9	1.75/7
p-values	1	0.98	0.55
(x)			
1st measurement	1.1/5	2.4/12	0.9/4
2nd measurement	0.2/2	1.4/10	1.7/6
3rd measurement	1.9/8	2.3/9	1/5
4th measurement	0.85/6	3.42/14	1/3
p-values	0.34	0.22	0.7
(y)			
1st measurement	0.3/2	1.2/9	0.3/1
2nd measurement	0.2/2	0.2/2	0.4/3
3rd measurement	1/5	1.1/5	2.9/12
4th measurement	0/0	1/2	1.62/8
p-values	0.26	0.23	0.33
L (z)			
1st measurement	2.6/10	5.5/11	2.6/8
2nd measurement	0.4/4	6.7/22	1.6/5
3rd measurement	1.8/8	3.4/11	1/5
4th measurement	0.85/3	6.71/45	2.37/5
p-values	0.38	0.18	0.61
L (θ)			
1st measurement	4.3/30	1.8/9	0.5/2
2nd measurement	2.1/10	1.2/6	2.4/15
3rd measurement	0.6/2	2.9/22	1.4/7
4th measurement	0.71/5	0.57/2	1.12/8
p-values	0.59	0.74	0.93

R: Right; L: Left

in the digital environment, and the field deviations in the (x), (y), and the (z) axes were examined according to the selected anatomical reference points. The mean intra-fractional error rates were found to be 2.2 mm, 2.3 mm, and 3 mm in the (x), (y), and the (z) axes, respectively. No significant relationship could be found between the deviation values on each axis and the weight, height, and gender characteristics of the patients.

Studies evaluating the comparison of two different set-up positions have been identified in the literature.[8,9,13] In our study, different from the literature, three different immobilization methods used for thoracic RT were compared for the 1st time. Unlike the aforementioned studies, the measurements were made by the researcher on the body in millimeter and not by the EPI. In our study, an evaluation with EPI was planned, but this could not be done due to the low quality of the EPI.

In our study, most of the major deviations were observed in the patient treated with lung boards. In the literature, it was seen that the measurements were made only on the (x) and the (y) axis, and in the study of Giraud and Halperin, additionally on the (z) axis.[8-10,13] However, in our study, in addition to the (x), (y), right and left (z) axis, the (θ) axis was measured in the craniocaudal direction in the lateral crosses in a more detailed way.

We observed a significant deviation with different accessories. In our study, it was found a deviation of more than 5 mm in both right and left (z) axes in patients who had been treated with the lung board (Group II). The mean field center deviations were determined as 5.66±4.15 mm in the right (z) axis (p=0.049), and 5.53±4.81 mm (p=0.015) in the left (z) axis. These values detected on the (z) axis were found to be similar to the proportions of the patients whose measurements were made with Halperin's T-bar.

In our study, the mean field center deviation's standard deviation values measured in each axis in the arm-supported lung board where the best stabilization was provided (1.63-4.81 mm) were lower than the values determined in the study of Halperin (3.7-5.4 mm).

The mean FCDV s (1.92-2.26 mm) in our study were close to the values found in the study of Giraud (2.2-3 mm). As a result of these data, the lung board providing the worst immobilization was found to have FCDV s similar to the literature.

In patients who had been treated with an arm along the body, the most suitable for the anatomical position, FCDV ranged between 0.41 and 3.06 mm. In this group, the mean FCDV was found to be 2.12 mm on the right and 2.13 mm on the left on the (θ) axis. These values were found to be higher than the values of the other two groups, although statistically non-significant. This difference was suggested to be due to the positional arm movements.

In patients treated with arms along the body, although the CT reference points were placed on the body during the simulation, it was seen that the side crosses coincided on the arm after the set-up. Although the patients do not move their trunks, any movement in the arms gives the impression that the fields are deviating. For this reason, for patients who received treatment with arms along the body, especially in posteriorly located tumors, it is suggested that planning the lateral crosses to allow drawing on the body and evaluating the set-ups by performing SSD control would be proper.

In our study, although the difference among the treatment fractions measured in the three groups of patients was not statistically significant, the deviation values in the right (z) axis in Group II were determined to gradually decrease in the following days of the treatment. As a result of this finding, it can be thought that as the treatment days progress, the patients get used to the treatment and can be immobile during the treatment.

It should be noted that a 45 mm maximum field center deviation was observed in this study. In addition, it was observed that the maximum value of mean intra-fraction field center deviation could reach 15 mm. It should be considered that these large deviations may have important clinical consequences in hypofractionated treatments such as SRS/SBRT which require high conformality and a steep dose gradient.

In the inter-fractional measurements, for Group I, the mean deviation value on the left (θ) axis was observed to be about two-fold greater than the other mean values, and the maximum value was 30 mm maximum in one patient. When the data were analyzed, the patient who had this value was found to be under-educated, to have chronic obstructive lung disease, advanced stage small cell lung carcinoma with solid organ and lymph node metastases, KPS 60 and a pain level of 6/10. This high FCDV was suggested to develop from the above-mentioned negative factors.

In the review of Coen et al. investigating set-up errors, in all studies including 8-35 patients and based on EPI measurements, mean values were provided, as in our study. The magnitude of systematic and random errors was observed to range between 1.8 and 5.4 mm in the review. Our range was similar to the literature.

The relationship between the FCDV and the general condition, age, the patient's pain, the indoor-outdoor temperature difference, and the set-up time was investigated. However, the statistical interpretation of some parameters was incompatible with the clinical importance. This situation is thought to be due to the small number of patients.

The strength of our study was that the evaluation of three different set-up positions using different devices with four axes in thoracic irradiation and some possible factors that may have affected the patient movements was evaluated in the same study. The inadequacy of our study was the margin of error due to manual measurements and the insufficient quality of the EPI films that were initially planned to be evaluated.

CONCLUSION

All we know is that today very advanced immobilization systems are used such as wing boards and vacuum beds. However, there are also clinics in underdeveloped countries that still only have to use a lung board. It is necessary to perform immobilization using arm supports in patient groups that still need to use lung board, which is the most frequently used immobilization apparatus in daily routine. Treatment with arms along the body is another alternative for patients for whom treatment with oblique fields is foreseen. In patients treated with arms along the body, we recommend placing the lateral cross of the treatment field on the body instead of the arms, and at the end of the treatment of each field, the SSD and both lateral crosses should be checked. It was observed that the movement values of the patients during the treatment could increase up to 45 mm. Therefore, at the end of the treatment of each field, it would be correct to check the fields in all axes and directions by entering the treatment room. It is recommended that the patient set-ups should be completed as soon as possible; as the treatment time prolongs, the field center deviations become more evident. It is thought that the quality of the set-up can be improved, and possible errors can be minimized with climatization systems that can balance the temperature difference between the indoor and the outdoor and if hypofractionated ablative RT is planned for the patient more modern immobilization devices have to be need.

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Ethics Committee Approval: The study was approved by the Dokuz Eylül University Ethics Committee (no: 2011/09-19, date: 24/03/2011).

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